MST121/MS221 GM

The Open University

USING MATHEMATICS
EXPLORING MATHEMATICS

A Guide to Mathcad

A GUIDE TO MATHCAD

5.1

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Contents

A **Quick reference** guide is provided on the back page.

How to use this Guide

A Guide to Mathcad is a reference manual describing the Mathcad commands and features used in MST121 and MS221 (the ‘course’). It assumes that your computer is operating under *Windows 98* or a later version (*2000*, *XP* etc.). Note that all the pictures of screens shown in this Guide are taken from *Windows XP* (Home). If you have a different version of *Windows*, then your screen may look slightly different to these pictures, but Mathcad will operate in a similar way.

The contents are grouped into broad areas of Mathcad use.

◊ To find a particular piece of information, try the alphabetic listing in the **Glossary**, on page 4.

◊ To look up a Mathcad **error message**, turn to page 62 at the back of this Guide.

The back page provides a summary of the key features of Mathcad in **quick reference** format.

(Use of Mathcad’s on-screen help and full reference manual is discussed on pages 59 to 61.)

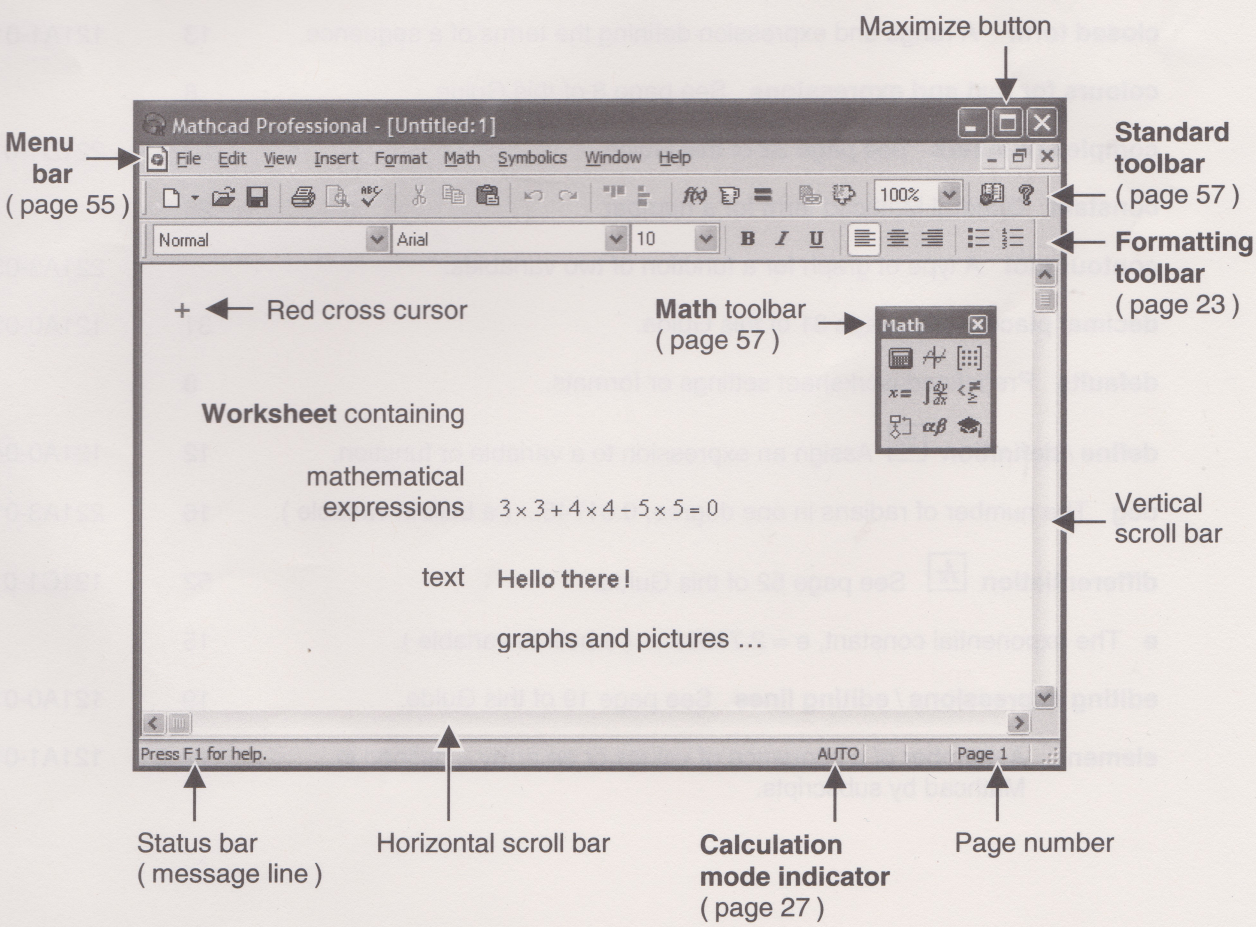
Notation

This Guide uses ♦ filled diamonds to indicate steps you should follow, and
! exclamation marks to highlight potential Mathcad problems.

Keystroke entry sequences are written in the style used in the course files.
For example – `[Ctrl]r` , with special keys shown enclosed within square brackets.

All mouse clicks refer to the left mouse button, unless stated otherwise.

The Mathcad window



Glossary

Below is a glossary of terms used in the MST121 and MS221 Mathcad files and Computer Books. The right-hand columns give page references to the term in this Guide and file references to the Mathcad file in which the term is first used or explained.

Term	Description	Page	File
argument	A value, variable or expression entered into a placeholder.	17, 41	
array	General Mathcad term for a vector or matrix – a list of numbers.	50	121B2-01
assign a value to	See define / definition.	12	121A0-04
automatic mode	Automatic calculation and updating of results.	27	
built-in function	Standard function predefined in Mathcad. Examples – cos, sin, tan, exp, ln and log.	16	
built-in variable	Special variable already defined when you start Mathcad. Examples – π, e and ORIGIN.	15	
calculation mode	Automatic (auto) or manual calculation mode.	27	
Calculator toolbar	A toolbar that can be used like a pocket calculator.	58	121A0-04
ceiling function / ceil(x)	Smallest integer which is greater than or equal to x. (A built-in function.)		
clipboard	A temporary store to which information is cut or copied and from which information is pasted.		
closed form	A range and expression defining the terms of a sequence.	13	121A1-01
colours for text and expressions	See page 8 of this Guide.	8	
complex numbers	See page 32 of this Guide.	32	221D1-01
constant	General Mathcad term for a number.	26	
contour plot	A type of graph for a function of two variables.		221A3-03
decimal places	See page 31 of this Guide.	31	121A0-03
defaults	Predefined worksheet settings or formats.	8	
define / definition $\boxed{:=}$	Assign an expression to a variable or function.	12	121A0-04
deg	The number of radians in one degree, 0.01745... (a built-in variable).	16	221A3-01
differentiation $\boxed{\frac{d}{dx}}$	See page 52 of this Guide.	52	121C1-01
e	The exponential constant, e = 2.71828... (a built-in variable).	15	
editing expressions / editing lines	See page 19 of this Guide.	19	121A0-01
element	A member of a sequence of values or an array – defined in Mathcad by subscripts.	12, 51	121A1-01

equation Two expressions separated by the special Mathcad ' = ' sign.	43	121A3-02
error message See page 62 at the back of this Guide for advice.	62	
evaluate expression Display the result of an arithmetic expression.	28	
evaluate symbolically See page 45 of this Guide.	45	
expand A symbolic keyword used to expand (multiply out) an expression.	47	121A0-05
exponential threshold A setting which determines when numbers are shown in scientific (exponential) notation.	31	121A0-03
factor A symbolic keyword used to factorise an expression.	47	121A0-05
expression A number, formula or equation.	17	
Find A Mathcad function to find the answer in the solve block method.	43	121A3-02
floor function / floor(x) Greatest integer which is less than or equal to x.	16	
Formatting toolbar The row of text formatting options below the menu bar.	23	
format The general appearance of text, numbers or graphs on the screen.	23, 31, 39	
function See pages 15 and 16 of this Guide.	15, 16	
Given A Mathcad keyword in the solve block method.	43	121A3-02
graph See page 35 of this Guide.	35	
graph format The appearance of a graph display. Examples – axis labelling, scale, trace type.	39	121A1-01
Greek letters For details of how to enter, see page 18 of this Guide.	18	
grid lines A grid of lines superimposed on a graph – a formatting option.	39	121A2-02
Help A menu used to access Mathcad's on-screen help facilities.	59	
if A Mathcad function for choosing one of two values based on a condition.	16	221B3-03
inherited values See 'Re-defining variables' on page 15 of this Guide.	15	
integral See page 53 of this Guide.	53	
interrupting calculations [`Esc`] key – see page 27 of this Guide.	27	
keyboard short-cut A sequence of key presses which select a command. (An alternative to selecting with a mouse click.)	18, 55, 56	
legend Key to accompany a graph – a formatting option.	40, 41	
linebreak A new line in a text box, created by pressing [`Enter`].	21	
manual mode Calculation and updating of results controlled by the user.	27	
markers Placeholders added to a graph to enable plotting of horizontal and vertical reference lines – a formatting option.	37	121A1-02

Math toolbar See page 57 of this Guide.	57	121A0-04
matrix See page 50 of this Guide.	50	121B2-01
menu A list of options from which you can choose a Mathcad command.	55	
message line Alternative name for the status bar.	3	
mod function / mod(a,n) The remainder of a on division by n. (A built-in function.)	16	221D2-01
multiplication See page 26 of this Guide.	26	
numerical format See result format.	31	121A0-03
online documentation An on-screen version of the full Mathcad manual.	61	
on-screen help See page 59 of this Guide.	59	
ORIGIN Specifies the subscript for the first element in a list or array. (A built-in variable.)	15	121A1-01
output General term to describe Mathcad results shown on the screen.	28	
output table General term to describe a table of Mathcad results.	29, 30	
pagebreak A solid or dotted horizontal line running across the screen indicating the start of a new page in a long worksheet.	10	
pi $\pi = 3.14159...$ (a built-in variable) .	15	121A0-04
placeholder A small black rectangle into which information is entered.	17	
polar plot A graph that can be used to represent complex numbers.		221D1-01
polyroots A Mathcad function which returns all the roots of a polynomial.	44	221D1-02
printing See page 10 of this Guide.	10	
range variable m..n A variable that takes on a range of values when used.	14	121A1-01
recurrence system A starting value, range and expression relating each term in a sequence to one or more previous terms.	13	121B1-01 221A1-01
refresh The process of re-drawing the screen, to obtain an up-to-date view.	27	121A0-02
region The area on the screen occupied by an expression, a graph, text or a picture. A Mathcad worksheet is a collection of regions.	24	121A0-02
Resource Center Part of Mathcad's on-screen help system.	60	
result format Settings which control how results are shown. For example – the number of decimal places.	31	121A0-03
rnd function / rnd(x) Generate a random number between 0 and x. (A built-in function.)	16	221B3-03
scalar A single number.		
scientific notation See exponential threshold.	31	121A0-03

scrolling table	A table which scrolls to reveal all the values.	29, 30	121A1-02
series	A symbolic keyword for expanding an expression to a Taylor series.	47	221C3-01
solve	A symbolic keyword used to solve an equation.	48	121A3-03
solve block	A numerical method to solve a system of equations.	43	121A3-02
Standard toolbar	Row of buttons immediately below the menu bar.	57	
status bar	Area at the bottom of the Mathcad window used for messages.	3	
subscripted variable $\boxed{x_n}$	See page 13 of this Guide.	13	121A1-01
surface plot	A graph of a function of two variables.		221A3-03
symbol	A data marker for graph points such as +, x (a formatting option).	39	121A1-01
symbolic calculations / Symbolic toolbar	See page 45 of this Guide.	45	121A0-05
table of values	A sequence of values displayed as a (scrolling) table.	29, 30	121A1-01
text box	A box within which text may be inserted, edited or deleted.	21	121A0-01
text format	The appearance of text, e.g. bold, superscript.	23	
tick marks	Marks made on the axes of graphs to indicate the scales.	40	
Tip of the Day	Part of Mathcad's on-screen help system.	60	
toggle	Switch between two modes of Mathcad operation. For example – automatic / manual calculation.	27	
TOL	Determines the accuracy of some numerical methods. (A built-in variable.)	15	
toolbar	Rows of buttons which you can use to select Mathcad options.	57	
trace (curve)	The line or symbols plotted on a graph.	40	121A1-01
trace (graph)	Obtain a read-out of graph coordinates.	42	121A2-01
trailing zeros	Zeros added to a number to display a fixed number of decimal places, e.g. 6.000 (a formatting option).	31	121A1-05
Undo	A command on the Edit menu to undo the last thing you did.	17, 19, 55	
variable	A quantity that can vary ; it is represented by a variable name.	12	
vector	See page 50 of this Guide.	50	
word-processing	See page 21 of this Guide.	21	
x-y plot	A Cartesian graph – one with x- and y-axes !	35	121A1-01
zero threshold	A setting to determine when numbers are shown as zero. (In the 'Result Format' option box, on the 'Tolerance' tab.)	31	
Zoom... (worksheet)	A command on the View menu to magnify or reduce the view of the entire worksheet.	9, 56	
zoom (graph)	Magnify a portion of a graph.	42	121A3-01

Starting Mathcad

- Double-click on the **Mathcad 2001i Professional** short-cut icon on your *Windows* desktop.
  (Alternatively, open the Start menu ; Programs ; MathSoft Apps ; and select the Mathcad 2001i Professional item. See MST121 Chapter A0 for further details.)

General features of Mathcad worksheets

Mathcad worksheets consist of mathematical expressions (numbers, formulas and equations), graphs, text (words and sentences) and pictures.

These items can be placed anywhere in the worksheet, and are created at the position marked by the red cross cursor. Each item forms a *region* in the worksheet.

Mathcad processes the information in a worksheet in the same way as you read it : from left to right and top to bottom, going down the screen line by line.

Worksheets may be longer than the one 'screenful' you can see in the Mathcad window. Use the vertical scroll bar or [`Page Up`] / [`Page Down`] keys to move up and down a worksheet, to bring unseen parts into view.

Worksheets may also be wider than one 'screenful', with information placed beyond the right-hand margin (the solid vertical line). Use the horizontal scroll bar to move left and right in a worksheet.

On-screen help with using Mathcad is available from the menu bar. Select the **Help** menu and **Mathcad Help**, then choose the 'Contents' tab for details of basic Mathcad procedures, or the 'Index' or 'Search' tabs to search for a particular topic. Please note that this help is provided by MathSoft, the makers of Mathcad – it is NOT specific to MST121 and MS221. (See page 59 of this Guide for further details.)

Default worksheet settings

The Mathcad worksheets supplied for MST121 and MS221 use the following default settings. (These settings will also be used for any new (Normal) worksheets which you create yourself.)

Built-in variables ORIGIN has the value 0. (See page 15 of this Guide for further details.)

Calculation mode Automatic. (See page 27.)

Fonts and colours for text and mathematical expressions

◊ Text — Arial 10pt, navy blue.

◊ Expressions — Times Roman 10pt, black.

To change the fonts and colours, do the following.

- Text — Select **Style...** from the **Format** menu.
  Choose 'Normal' from the list of text styles,
  then click on the **Modify...** button, followed by the **Font...** button.
  You can then change the font, font style, font size or colour.

- Expressions — Select **Equation...** from the **Format** menu.
  To change the colour only, you can alter the 'Default Equation Color', but to change the font you need to modify the style for both 'Variables' and 'Constants'. To do this, select each in turn from the list of style names, and click on the **Modify...** button.

Graphs — Line graph ; the first trace drawn is a solid red line. (See page 40.)

Multiplication — When multiplying numbers, display the multiplication sign x.
(**Math** menu, **Options...**, 'Display', view 'Multiplication' as 'AutoSelect'.)

Result format — Number of decimal places 3 and Exponential threshold 3.
(See page 31.)

Special features of MST121 and MS221 worksheets

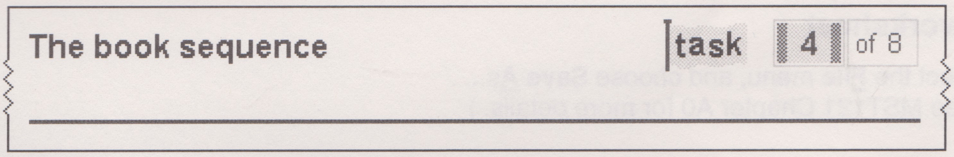
Worksheet layout

The contents of MST121 and MS221 worksheets are divided up into a series of 'pages', with a title at the top and an end-of-worksheet marker at the bottom. The worksheets fit within the *width* of the Mathcad window but most are *longer* than the window, consisting of several pages. (Note that most pages are laid out in 'portrait' format, but a few are laid out in 'landscape' format.)

Your view of a course worksheet will depend upon the size of computer screen you are using. A large (high-resolution) screen may show additional blank pages off to the right. To magnify your view, to see just one page width, use the **View** menu and **Zoom...** option. (If you experience any problems with this option, then leave the zoom magnification at its normal value, 100%.)

The first page includes a list of contents, which may be accompanied by a brief introduction.

Subsequent pages each have a heading, a flag indicating the page 'type', a page number in the top right-hand corner, and a thick line marking the end of the page.

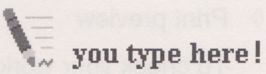


Getting around ...

- To move up and down within a page, use the vertical scroll bar or [`Page Up`] / [`Page Down`] keys, which, despite their names, actually move the red cross cursor only a few lines.
- To move through a worksheet from one page to the top of another page :
  press [`Shift`][`Page Up`] to go to the previous page, [`Shift`][`Page Down`] to go to the next page ; or choose **Go to Page...** from the **Edit** menu, and enter the page number you require.

Entering your own expressions into the worksheet

When a task requires you to enter information in a particular place, the 'pencil' symbol is used to show you the position on the screen at which to type.



Help

Assistance and explanations are provided on the pages within each course worksheet, with hints and answers for the tasks, and detailed Mathcad instructions where appropriate.

Creating your own worksheets

To create a new, empty worksheet, do the following.

- Select the **File** menu, and choose **New...** .

  (Alternatively, type `[Ctrl]n` or click on the **New** button on the 'Standard' toolbar (see page 57). Both these alternative methods create a new (Normal) worksheet immediately, and do not require the additional step below.)

- In the list of templates, 'Normal' should be selected by default. If not, click on it. Click on the **OK** button to create a new (Normal) worksheet.

A new worksheet is also created automatically, ready for you to use, when you start Mathcad.

It is a good idea to enter some text in your worksheets (see page 21), alongside the mathematical expressions and graphs. Some explanatory text, including a title and date at the top, will help you to recall what the worksheet was all about if you return to it on a later occasion.

When constructing a long worksheet, you may like to divide it into separate pages. (See Printing / pagebreaks at the bottom of this page.)

Opening, saving, printing and closing worksheets

Opening a worksheet

- Select the **File** menu, and choose **Open...** .
  (See MST121 Chapter A0 for more details.)

You can have several Mathcad worksheets open at the same time if you wish !

Saving a worksheet

- Select the **File** menu, and choose **Save As...** .
  (See MST121 Chapter A0 for more details.)

Notes

The other menu option **File** and **Save** overwrites the original copy of a worksheet, and replaces it with the current version, with NO further prompting.

Printing a worksheet

! Please note
You will, on occasion, need to supply Mathcad print-outs for Tutor-Marked Assignments. However, you are NOT required to print out any of the course files (e.g. 121A1-01, -02, -03, ...).

◊ Print preview

To check your worksheet's layout *before* printing, choose **Print Preview** from the **File** menu.

◊ Pagebreaks

A long worksheet is automatically split into pages by Mathcad and your printer. These (soft) pagebreaks are indicated by dotted horizontal lines running across the screen. You cannot add or remove soft pagebreaks directly.

However, if you want to break the page at a different place, then you need to insert a (hard) pagebreak yourself. To do this, position the red cross cursor on the line where you want the break to be, then choose **Page Break** from the **Insert** menu. These pagebreaks are shown as solid horizontal lines – you may have noticed them between the pages of the course worksheets. To remove a hard pagebreak : hold down the [`Shift`] key, and click on the line to select it ; then use the **Edit** menu and **Cut**.

◊ Margins and wide worksheets

To set the margins, select the **File** menu and **Page Setup...** .
The right margin appears as a solid vertical line in the Mathcad window.

A wide worksheet, where information has been placed beyond the right margin, is divided into vertical strips of pages for printing purposes. To avoid printing any pages to the right of the right-hand margin, select **Print single page width** in the 'Page Setup' option box. (You may find that changing the 'Orientation' from 'Portrait' to 'Landscape' in this option box allows all the information to fit within the right-hand margin.)

Printing

- To print all or part of a Mathcad worksheet, select the **File** menu and **Print...** .

This brings up the 'Print' option box. You can choose to print all of your worksheet or only particular pages. Make sure that your printer is switched on and has some paper, then click on the **OK** button to print.

Closing a worksheet

- Select the **File** menu, and choose **Close**.

If you have made changes to the worksheet since it was last saved, you will be asked if you wish to save the current version before closing.

Exiting from Mathcad

- Select the **File** menu, and choose **Exit**.
(See MST121 Chapter A0 for more details.)

Defining variables and functions

Defining variables

To **define** a variable, you assign a value to it – **variable name := value** , example $r := 1.5$

- Enter a name.
- Click on the 'Definition' button := on the 'Calculator' toolbar
  or use the keyboard alternative **:** (the colon, obtained by typing [**Shift**] and **;** together).
- Enter a value.
- To complete the definition, click elsewhere on the page or press the [**Enter**] key.

Example $\boxed{r}$ ➡ := ➡ $\boxed{r := \blacksquare}$ ➡ $\boxed{r := 1.5}$ ➡ $r := 1.5$ or type **r:1.5**

A variable name can be a single letter, **r**, a letter followed by a number, **T1**, or a word, **step**. The name must start with a letter, and no spaces are allowed within the name. The underscore character _ (type [**Shift**]-) can be used as a separator instead of a space, e.g. **sunny_day**.

The value at the right-hand side of the definition must be a number. However, this number can be a constant or the result of a calculation, which in turn may also involve other variables and functions which have already been defined.

Examples $V := 71$ $V := 10 \times 3.142 \times 1.5^2$ $V := 10\pi r^2$ $V := A h$

Variables must be defined *above* the place in the worksheet where they are first used.
(On the same line and to the left counts as above, but to the right counts as below.)

If you try to use a variable before it has been defined, Mathcad highlights the unknown variable in red, and clicking on the offending expression displays the error message 'This variable or function is not defined above'. Note that variable names are case specific : **r** and **R** are two different variables in Mathcad.

See Mathcad file 121A0-04, pages 3, 5 and 6.

Related topics in this Guide : Re-defining variables, page 15 ; Undefined variables, page 62.

Defining subscripted variables

To define a subscripted variable – **name** $_{\textbf{subscript}}$ **:= value** , example $u_3 := 16$

- Enter a name.
- Click on the 'Subscript' button x_n on the 'Matrix' toolbar or use the keyboard alternative **[** (left square bracket).
- Enter a subscript.
- Click on the 'Definition' button := on the 'Calculator' toolbar or use the keyboard alternative **:** (colon – type **[Shift];**).
- Enter a value.
- To complete the definition, click elsewhere on the page or press the [**Enter**] key.

Example

$\boxed{u} \Rightarrow \boxed{x_n} \Rightarrow \boxed{u_{\blacksquare}} \Rightarrow \boxed{u_3} \Rightarrow \boxed{:=} \Rightarrow \boxed{u_3 := \blacksquare} \Rightarrow \boxed{u_3 := 16} \Rightarrow u_3 := 16$ or type **u[3:16**

See Mathcad file 121A1-01, page 2.

Related topic in this Guide : ORIGIN, page 15.

Several subscripted variables can be defined at the same time by using a range variable as the subscript – two methods are given below. (See page 14 for details of range variables.)

◊ Closed forms

The range variable may be used on both sides of the definition for a subscripted variable to calculate the terms of a sequence. (The **closed form** formula makes up the right-hand side of the definition.)

For example

First term of the sequence has subscript 1 $\quad ORIGIN := 1$

Range $\quad n := 1, 2 .. 12 \quad$ Definition $\quad b_n := 5 + 3(n - 1)$

Equivalent to $\quad b_1 := 5 \quad b_2 := 8 \quad$ ... up to $\quad b_{12} := 38$

See Mathcad file 121A1-01, pages 4 and 5.

◊ Recurrence systems

To implement a recurrence system in Mathcad, you use a range variable to define a sequence of subscripted variables. (The numbers below, e.g. [1], refer to the examples on the next page.)

- If necessary, define the variable ORIGIN to match the subscript of the first element [1].
- Define a subscripted variable for the starting value, the first term of the sequence [2]. This step may be interchanged with the next one.
- Define a range to calculate the desired number of terms [3]. This will depend on the subscript used for the first term, which term the recurrence relation defines, e.g. b_n or b_{n+1}, and the number of terms required.

◆ Enter the recurrence relation, i.e. a definition for the terms of the sequence [4].
Note that the range variable appears in the expressions for the subscripted variables.
Mathcad carries out this definition once for each value of the range.

Examples

[1]	ORIGIN := 1	[1]	ORIGIN is zero by default
[2]	$b_1 := 5$		
[3]	$n := 1,2..11$	[3]	$N := 20 \quad i := 0,1..N-1$
[4]	$b_{n+1} := b_n + 3$	[2] and [4]	$P_0 := 3200$ and $P_{i+1} := P_i\left[1 + r\left(1 - \frac{P_i}{E}\right)\right]$

See Mathcad files 121B1-01 and 221A1-01.

Related topics in this Guide : Subscripted variables, page 13 ;
Defining range variables, page 14 ; ORIGIN, page 15 ; Entering expressions, page 17.

Defining range variables

To define a range variable – **name := starting value, next value .. final value**

Example $i := 0,1..3$

◆ Enter a name.

◆ Click on the 'Definition' button [:=] on the 'Calculator' toolbar
or use the keyboard alternative **:** (colon – type [**Shift**]**;**).

◆ Enter a starting value followed by a comma and the next value.

◆ Click on the 'Range Variable' button [m..n] on the 'Matrix' toolbar
or use the keyboard alternative **;** (a semicolon).

◆ Enter the final value.

◆ To complete the definition, click elsewhere on the page or press the [**Enter**] key.

Example [i] → [:=] → [i := ▮] → [i := 0,▮] → [i := 0,1▮] → [m..n] → [i := 0,1..▮] → i := 0,1..3

or type **i:0,1;3**

A range variable takes on a range of values, separated by uniform steps. In the example above, the variable **i** takes the values **0**, **1**, **2** and **3**. The step size is determined by the difference between the 'next value' and the 'starting value'.

An alternative way to think of and construct the definition is
name := starting value, starting value + step size .. final value

Range variables can ascend or descend in value, e.g. **i := 0, 1 .. 10** or **i := 10, 9 .. 0**
If the 'next value' is omitted, then Mathcad uses a step size of 1 or –1, whichever is appropriate.

See Mathcad files 121A1-01, page 3, and 121A2-02, page 6.

Related topics in this Guide : Closed forms, page 13 ; Recurrence systems, page 13 ;
Tables of values – Using a range variable, page 30 ; Graphs, page 35.

Defining functions

To define a function – **function name := expression** , example $f(x) := 4\,x^3$

The procedure is very similar to the one used to define a variable. (See page 12.)

- Enter a function name, followed by left round bracket '(', variable name, right bracket ')'.
- Click on the 'Definition' button on the 'Calculator' toolbar or use the keyboard alternative : (colon – type `[Shift];`).
- Enter an expression, which uses the named variable from the left-hand side.
- To complete the definition, click elsewhere on the page or press the `[Enter]` key.

The expression on the right-hand side of the definition may include numbers, mathematical operators, variables and other functions which you have already defined or are built into Mathcad.

Example $y(t) := \sin(t) + \sin(13t)$

This could be entered by the keystroke sequence `y(t):sin(t)+sin(13*t)`

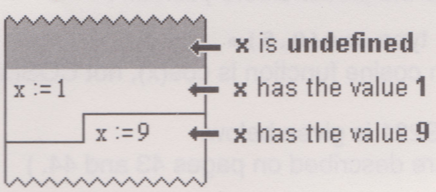
See Mathcad file 121A3-01, page 2.

Related topic in this Guide : Built-in or predefined functions, page 16.

Re-defining variables and functions

Variables and functions can be defined more than once in the same worksheet.

A definition involving ':=' affects everything below and to the right of it in the worksheet.



Mathcad will simply use the first definition for all expressions below the first definition and above the second.

For expressions below the second definition, Mathcad uses the second definition.

However, care is needed when re-defining sequences of subscripted variables. Suppose that the first definition creates ten terms, b_1, b_2, ..., b_{10}, but the second defines only five terms, b_1, b_2, ..., b_5 . The values b_6, b_7, ..., b_{10} are still defined, as they are 'inherited' from the first definition.

One way to avoid any possible confusion is not to re-define subscripted variables !
Other types of variables and functions are not affected by this problem.

Built-in or predefined variables

There are a handful of special variables that are already defined when you start Mathcad. They either have a standard mathematical value, like π and **e**, or are used to control how Mathcad works, like **ORIGIN** and **TOL** (**Math** menu, **Options...**, 'Built-In Variables').

Although Mathcad predefines these variables, you can still re-define them for your own use. Note that variable names are case-sensitive, e.g. ORIGIN must be entered in capital letters.

Variable	Default value	
π	3.14159...	Pi – click on the 'Pi' button on the 'Calculator' toolbar or use the keyboard alternative `[Ctrl][Shift]p` .

Variable	Default value	
e	2.71828...	The exponential constant – simply type **e**
deg	0.01745...	The number of radians in one degree, e.g. $180\,\mathrm{deg} = 3.14159...$
ORIGIN	0	Specifies the first element used for lists, tables and arrays.
TOL	0.001	Determines the accuracy of some numerical methods.

Notes

The variable deg is included in the systems of units built into Mathcad. So deg is not defined if these units are switched off – **Math** menu, **Options...**, 'Unit System' tab, Default Units 'None'.

When working with subscripted variables, the value of ORIGIN should match the first subscript required. By default, Mathcad automatically begins each sequence with an element with subscript zero, e.g. b_0. See Mathcad file 121A1-01, page 4.

Related topics in this Guide

ORIGIN : Defining subscripted variables, page 13 ; Recurrence systems, page 13 ;
Tables of values, page 29 ; Labelling matrix elements, page 51.

TOL : The solve block, page 44 ; Evaluating a definite integral numerically, page 53.

Built-in or predefined functions

Mathcad has an extensive library of built-in functions, including all the standard trigonometric, logarithmic and exponential functions. There are also special functions, such as **floor** (used to round down a number to an integer) and **rnd** (used to generate a random number).

The complete list of functions can be seen by selecting the **Insert** menu and **Function...** .

You can use this menu option to insert a function into your worksheet without having to type it. However, you still need to put the appropriate values into the placeholders yourself !

Alternatively, you can enter these functions directly, e.g. type `cos(0.5)=` .
Note that function names are case-sensitive : the built-in cosine function is cos(x), not COS(x).

Details of one of the special built-in functions used in MS221 is given below.
(In addition, the built-in functions **Find** and **polyroots** are described on pages 43 and 44.)

◊ **if**

The **if** function chooses one of two values based on a condition.

if(condition,a,b) returns the value **a** if the condition is true, and **b** if the condition is false.

Examples

$x := 7 \qquad \mathrm{if}\left(x > 5, x^2, x\right) = 49$

$x := 3 \qquad \mathrm{if}\left(x > 5, x^2, x\right) = 3$

Several if statements can also be combined together.

Example

$\mathrm{if}(p < 0.8, f(x), \mathrm{if}(p < 0.89, g(x), \mathrm{if}(p < 0.98, h(x), k(x))))$

This expression returns :

f(x) if $p < 0.8$; g(x) if $0.8 \le p < 0.89$; h(x) if $0.89 \le p < 0.98$; k(x) if $p \ge 0.98$.

See Mathcad file 221B3-03, pages 3 and 4.

Related topic in this Guide : How to construct equations and inequalities, page 43.

Entering and editing expressions

Also see :

Entering expressions

Entering expressions in Mathcad is a matter of putting information into a series of *placeholders*. These are the small black rectangles which appear as you click on the toolbar buttons or use the equivalent keyboard commands.

Blue editing lines around the placeholder indicate that it is selected, ready to receive information.

Examples $y := ▮$ $u_{▮}$ $j := 0, 1 .. ▮$ $\int_{▮}^{▮} ▮ \, d▮$

♦ To select a particular placeholder, you can click on it.
If there are several placeholders, then the [**Tab**] key can also be used to select each in turn.

As you enter information into a placeholder, the information is inserted immediately to the left of the vertical editing line. If you make a mistake, then pressing [**Backspace**] will rub out the last number or letter you entered. (You may also be able to use the **Edit** menu and **Undo**, to undo the last thing that you did.)

Examples $y := 5$ u_3 $j := 0, 1 .. 100$ $\int_{▮}^{▮} \sin(x \, d▮$

♦ To finish entering an expression, you can either click elsewhere on the page or press the [**Enter**] key. (This key may alternatively be labelled [**Return**] or just [↵].)

Dos and Don'ts

Do remember to include a multiplication sign where appropriate, e.g. enter '**a*x**' not '**ax**'.
Don't use the spacebar to insert extra spaces in an expression. The spaces look after themselves !

Related topics in this Guide : Basic mathematical operators, page 26.

Division, powers, subscripts and the spacebar

Extra care is needed when entering expressions which involve division, powers or subscripted variables. After entering the division sign, `/`, entry continues in the denominator, below the line. In the case of powers, after entering the power, entry continues in the index position above the line, whilst subscripts continue below the line, still within the subscript.

The spacebar [`Space`] is used to select (enclose within the blue editing lines) parts of the expression entered so far. This enables entry to continue as usual (on the line) to construct the remainder of the expression. The number of presses of the spacebar required depends upon the nature of the expression.

Examples	Key sequence	'Calculator' and 'Matrix' toolbar buttons
$\frac{1}{4} + 6 = 6.25$	`1/4[Space]+6=`	1 / 4 [Space] + 6 =
$x^2 - 1$	`x^2[Space] -1`	x x^2 [Space] − 1
$F_{n+1} + F_n$	`F[n+1[Space][Space]+F[n`	F x_n n + 1 [Space][Space] + F x_n n

See Mathcad files 121A0-03, page 3, and 221A1-01, page 3.

Greek letters in expressions

Greek letters can be used in expressions and as variable names in Mathcad.

Examples $\alpha := 2$ $\beta := 3$ $\theta := \frac{\pi}{3}$ $\cos(\theta) = 0.5$

There are two ways to enter a Greek letter.

A keyboard way.

- ♦ Type the roman equivalent, then press [`Ctrl`]`g`.
  For example, type **a** followed by [`Ctrl`]`g` – the 'a' will change into an 'α' (alpha) .

  The roman equivalents for the Greek letters used in the course files are :
  alpha α – a ; beta β – b ; pi π – p ; theta θ – q ; phi ϕ – f and psi ψ – y.

Or a mouse / click way.

- ♦ Click on the Greek letter buttons on the 'Greek' toolbar.

  (To reveal this toolbar, either click on the 'Greek' button αβ on the 'Math' toolbar, or select the **View** menu, **Toolbars** and **Greek**.)

Notes

The Greek letter pi, π = 3.14159..., is a built-in variable in Mathcad. (See page 15.)

As π is so frequently used, there is a keyboard short-cut [`Ctrl`][`Shift`]`p`, and a 'Pi' button is also available on the 'Calculator' toolbar.

All the methods above can also be used to enter Greek letters in Mathcad text.

Related topics in this Guide : Greek toolbar, page 58 ; Defining variables, page 12.

Editing expressions : controlling the editing lines

- The first step is to click on the expression you wish to edit.
  (Alternatively, use the arrow keys to manoeuvre the red cross cursor over the expression.)

Mathcad encloses the expression in a black box and, where you clicked within the expression, there will be a pair of vertical and horizontal blue editing lines.

$$1 + 9 \times 10 - \frac{30}{5}$$

◊ **Vertical editing line** (used to insert extra information, change values, correct typing mistakes)

The vertical editing line indicates where information will be inserted into a mathematical expression and what you enter appears immediately to the left of this line.

The left and right arrow keys [←] and [→] move the vertical editing line along the expression one character at a time. (A character is a number, a letter, or an operator such as '+' or '–'.) The horizontal editing line is 'attached' to the vertical line and will move along too.

Pressing the [`Backspace`] key removes the character to the left of the vertical editing line, whereas pressing the [`Delete`] key rubs out the character to the right.

◊ **Horizontal editing line** (used to select large parts of an expression, to delete or copy)

The horizontal editing line (together with the vertical editing line) indicates the extent of the current selection in an expression.

Examples $1 + 9 \times 10 - \frac{30}{5}$ and $1 + 9 \times 10 - \frac{30}{5}$

Note that the vertical editing line can be at the left- or right-hand side of the selection.

The [`Insert`] key (this may just be labelled [`Ins`] on your computer) will switch the vertical editing line from one side of the current selection to the other. Such a switch does not change what is selected, but it allows you to insert extra information *before* (vertical editing line at the left-hand side) or *after* (vertical editing line at the right-hand side) the selection.

◊ **Selecting parts of an expression**

The length of the editing lines is controlled by pressing the spacebar [`Space`]. Each time you press [`Space`] the editing lines grow longer, until eventually they enclose (select) the entire expression. Pressing [`Space`] one more time brings the lines back to where they were before you began pressing the spacebar – the start of the cycle. (If a 'spacebar cycle' does not select what you want, then try a different starting position, by clicking elsewhere on the expression.)

Choosing the **Edit** menu and **Cut** (or pressing [`Ctrl]x`) will delete whatever is selected within the blue editing lines. The **Edit** menu **Copy** and **Paste** facilities can also be applied, allowing you to copy all or part of an existing expression and paste it into a new one.

As an alternative to using the [←], [→] and [`Space`] keys to position and control the editing lines, you can click on the expression and then drag across it, to highlight the selection. Pressing [`Backspace`] or [`Delete`] will delete whatever is highlighted like this, giving a quick way to delete things.

$$1 + 9 \times 10 - \frac{30}{5}$$

- To finish editing an expression, click elsewhere on the page or press the [`Enter`] key.

There are no hard and fast rules regarding how to edit an expression. Use of the vertical and horizontal editing lines is illustrated in the three basic editing techniques given on the next page. (If an edit does not work out as intended, then the **Edit** menu and **Undo** may be able to undo it.)

Related topics in this Guide :
How to apply a symbolic keyword, page 46 ; How to edit a matrix, page 50.

How to change the value at the right-hand side of a definition

- Click on the right-hand side of the definition.
  This places the blue editing lines wherever you clicked the mouse.
  Move the editing lines if necessary by pressing the left and right arrow keys [1].
- Rub out with the [**Backspace**] key [2] and enter the new value [3].
  (Pressing the [**Delete**] key will rub out forwards.)
- Click elsewhere on the page or press [**Enter**] to finish [4].

1 $r := 1.5$ ➡ $r := 1.5$ ➡ **2** $r := 1$ ➡ $r :=$ ➡ **3** $r := 2$ ➡ **4** $r := 2$

See Mathcad file 121A0-04, page 4.

How to change the operator (+ − * /) in an expression

The example below shows changing a multiplication to a division.

- Click on the expression and use the left and right arrow keys to place the horizontal editing line so that the operator is immediately to the left of this line [1].
- Press [**Backspace**] to delete the existing operator [2] and enter the new operator in its place [3].
- Click elsewhere on the page or press [**Enter**] to finish [4].

1 $1 + 9 \times 10 - 30 \times 5$ ➡ **2** $1 + 9 \times 10 - 305$ ➡ **3** $1 + 9 \times 10 - \frac{30}{5}$ ➡ **4** $1 + 9 \times 10 - \frac{30}{5}$

How to delete an entire expression

- Click anywhere on the expression.
- Press the spacebar [**Space**] repeatedly, to extend the editing lines until they select the entire expression – the vertical editing line can be at either end of the expression, as shown :

$3 \times 3 + 4 \times 4 - 5 \times 5 = 0$ or $3 \times 3 + 4 \times 4 - 5 \times 5 = 0$

- Then select the **Edit** menu and **Cut** (or press [**Ctrl**]**x**) to delete it.
  You can also delete it by pressing the [**Backspace**] key *twice* (if the vertical editing line is at the right-hand end of the expression), or by pressing the [**Delete**] key *twice* (if the editing line is at the left-hand end).

(Alternatively, you can use the 'click and drag' technique described on the previous page.)

Inserting or deleting blank lines in a worksheet

You can easily insert one or more blank lines into a worksheet, if you need more room to work.

- Click to position the red cross cursor where you wish to insert the blank lines.
- Press the [**Enter**] key one or more times – each key press will insert one blank line.

You can use a similar procedure to delete blank lines. Pressing [**Backspace**] will delete blank lines above the cursor position, while [**Delete**] will delete blank lines below the cursor position.

See Mathcad file 121A0-02, page 4.

Related topic in this Guide : How to move a region, page 24.

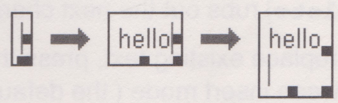
Text and pictures

Creating text regions and entering text

Mathcad lets you enter text anywhere within a worksheet, and also provides some word-processing facilities for formatting and checking the text.

In order to enter some text, you must first create a text region.
(If you just start typing, Mathcad thinks that you are entering a mathematical expression !)

- Move the mouse arrow to a blank space in the worksheet, then click to position the red cross cursor where you wish the text region to begin.
- Select the **Insert** menu, and choose **Text Region**
(or use the keyboard short-cut, type a double-quote " (given by [Shift]2).
- A small *text box* appears, with a red bar cursor inside.
Now begin typing your text.



  As you type, the cursor moves and the text box grows automatically.
  The box will continue to expand until it reaches the right-hand margin of the worksheet (the solid vertical line), when the text will wrap round to the next line below.

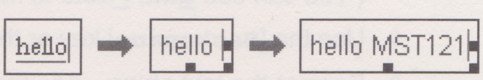
  To force a new line in the text box, press the [Enter] key.
  (This key may alternatively be labelled [Return] or just [↵].)
- To stop entering text, move the mouse arrow to a point outside the text region and click.
The box will disappear, leaving just the text. (Alternatively, press [Ctrl][Shift][Enter].)

Related topics in this Guide : Formatting text, page 23 ; Resizing a text region, page 25.

A quick way to enter text

If you just start typing, Mathcad thinks that you are entering a mathematical expression, but if you type a word followed immediately by pressing the spacebar [Space], then Mathcad knows that you intended to enter text.

For example, if you type **hello[Space]MST121**, the expression 'hello' changes into the text 'hello MST121'.



Pressing the spacebar here creates a text region automatically, and text entry then proceeds as described in the section above. (Note that this quick entry method doesn't work if the initial word contains a bracket or a comma.)

Entering Greek letters in text

The methods used to enter Greek letters within a text region are identical to those used to enter Greek letters in a mathematical expression. (See page 18 of this Guide for details.)

Text colour

By default, MST121 and MS221 worksheets use navy blue for the text colour.

For details of how to alter the default text colour, see
'Fonts and colours for text and mathematical expressions' at the bottom of page 8 of this Guide.

Related topic in this Guide : Formatting text, page 23.

Editing text

- ♦ To edit a piece of text, simply click on it !

  The text box and red bar cursor appear, allowing you to insert or delete text as you wish.
  (See the section below for details of how to delete a long string of text.)

- ♦ To finish editing text, move the mouse arrow to a point outside the text region and click.
  You can also finish by pressing [`Ctrl`][`Shift`][`Enter`].

Notes

Use the left and right arrow keys, [←] and [→], to move the cursor along the text one character at a time, into the required editing position. Any new characters you type will be inserted into the text immediately to the left of the cursor. Pressing [`Enter`] will start a new line in the text box.

Pressing [`Backspace`] will delete the previous character, to the left of the cursor, whereas pressing [`Delete`] rubs out the next character, to the right.

To replace existing text, press the [`Insert`] key (this may just be labelled [`Ins`]), which switches between insert mode (the default) and overtype mode.

Selecting a string of text within a text region, to copy, delete or format

To select a string of text *within* a text region, prior to copying, deleting or formatting.

- ♦ Click in the text region so that the text box and red bar cursor appear.
  If necessary, use the arrow keys to manoeuvre the cursor to the start of the portion of text that you wish to select.
- ♦ Then hold down the mouse button and drag across the text.
  Mathcad highlights the selected text.

Some selected text and

Once the text string has been selected, you can do the following.

- ◊ Use the **Edit** menu and **Copy** to copy the text string (to a blank space or another text box).
  Click where the copy is to be placed, then choose the **Edit** menu again and **Paste**.
- ◊ Use the **Edit** menu and **Cut** to delete the text string.
  (You can use **Edit**, **Paste** to move this text to another location if you wish.)
- ◊ Use the [`Backspace`] key or the [`Delete`] key to delete the text string.
- ◊ **Format** the text string – see the next section for details.

Notes – A single word in a text box can be selected by double-clicking on it.

Related topic in this Guide : Moving, deleting, copying and resizing regions, page 24.

Formatting text

Once a text string has been selected, you can format it, i.e. change its font, size, font style and effects, or colour.

◊ Font refers to the `typeface` used to write the text.

◊ Size refers to the siZe of the characters (measured in points, 72pt = 1 inch).

◊ Font style and effects refers to **bold**, *italic*, <u>underline</u>, $_{\text{sub}}$scripted or $^{\text{super}}$scripted forms.

To format some text, follow the steps below.

- Select a text string within a text region – this can be just a single letter or number. (See the previous section in this Guide for details of how to do this.)
- Select the **Format** menu and **Text...** . This bring up the 'Text Format' option box, which contains scrolling lists of the available fonts, sizes, styles and colours, and a series of check boxes for the effects.

You can also change the appearance of the paragraphs within a text region. (When entering text, a new paragraph is formed each time you press the [`Enter`] key to force a new line.) First click anywhere in the paragraph, then select the **Format** menu and **Paragraph...** to alter the text alignment (Left, Right, Center) and indentation, or to add numbers or bullet points to make a list.

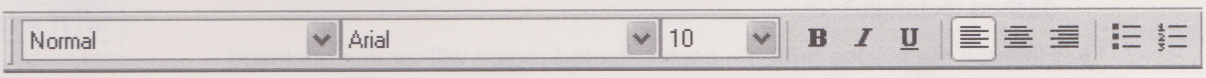
Mathcad also provides some built-in text styles, which you can apply by selecting the **Format** menu and **Style...** . (The default style is 'Normal' – Arial font, 10pt size, no effects, navy blue.)

Notes

When you edit existing text in a text region (see page 22) and start typing, the new text takes its format from the character immediately preceding it.

Most of the options described above are also available from the 'Formatting' toolbar.

Text style　　Font　　Size　　Effects　　Paragraph options



Checking text for spelling mistakes

- Select the **Edit** menu and **Check Spelling...** .

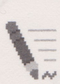
If any misspelled words are found, Mathcad will display an option box and suggest a replacement.

Mathcad checks all the text regions beneath the red cross cursor to the end of the worksheet. (Note that Mathcad checks only the text regions, it does NOT check mathematical expressions.)

Pictures

There are NO facilities within Mathcad itself for producing pictures or diagrams (other than graphs).

However, pictures can be created in other applications, such as the *Windows* Paint program, and pasted into Mathcad worksheets.

All the pictures you see in course worksheets, e.g. the pencil icon , are bitmap graphics.

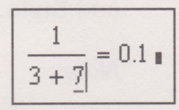
These pictures form regions in the worksheet and can be moved, copied, deleted and even resized just like other Mathcad regions (see page 24 of this Guide). They are there only to be looked at – nothing happens if you click on a picture, apart from the appearance of the black selection box around it ! Once a picture is selected in this way, you can choose the **Format** menu and **Properties...** to highlight it, or put a border around it.

Moving, deleting, copying and resizing regions

How to select a region

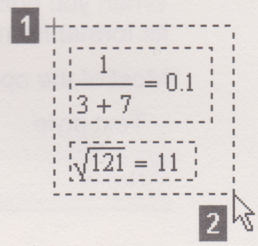
Each mathematical expression, graph, piece of text and picture forms a **region** in a Mathcad worksheet. Regions can be moved around the page, deleted, copied and (in the case of graphs, text and tables of numbers) resized.

Before you can do any of these operations, you must **select** the region, or regions, you require.



- To select a single region, simply click anywhere on it. Mathcad encloses the region in a solid black box.

To select two or more regions, a different ('lassoo-ing') procedure is used.

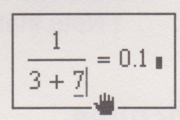


- Click a little away from the regions to obtain the red cross cursor [1].
- Click and drag towards the regions until they are all enclosed by black dashed rectangles [2].
- Release the mouse button – each selected region will remain enclosed by a black dashed rectangle.

(Alternatively, select the regions by holding down the [`Ctrl`] key as you click on each one.)

How to move a region

- Select the region(s) in the way described above.
- To move a single region, place the mouse arrow on the border of the black selection box to obtain a black hand cursor. When two or more regions are selected, you can place the mouse arrow within any of them to obtain the black hand cursor.



- You can now click and drag to move the region(s) to another location.

See Mathcad file 121A0-02, page 2.

How to delete a region

! If the region you want to delete is a single mathematical expression, then a different selection process is required. See 'How to delete an entire expression' on page 20 of this Guide.

- Select the region(s) you require. (See the top of this page for details.)
- To delete the region(s), choose the **Edit** menu and **Cut** ([`Ctrl`]`x`).
(When two or more regions are selected, you can also press [`Backspace`] or [`Delete`].)

Cutting, copying and pasting regions

- Select the region(s) you require. (See the previous page for details.)

! If the region is a single mathematical expression, then the techniques below apply only to the part of the expression enclosed by the blue editing lines. If you want to cut or copy the entire expression then press [`Space`] repeatedly, until the blue editing lines enclose it all. (For more details, see 'Editing expressions : controlling the editing lines', on page 19 of this Guide.)

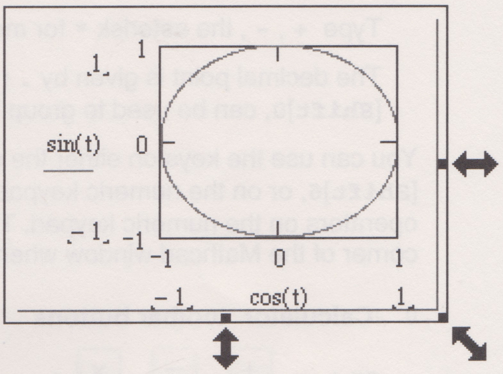
- Choose the **Edit** menu and **Cut** ([`Ctrl`]`x`) or **Edit** and **Copy** ([`Ctrl`]`c`).
  You can then position the red cross cursor elsewhere in the worksheet, and **Edit**, **Paste** ([`Ctrl`]`v`) to either move or copy the region(s) as you wish.

Resizing a graph

This technique involves changing the *physical* size of a graph, to make it look bigger or smaller on the page. It is not concerned with zooming in or out of the graph to get a different range of values, which is covered in 'Graphs – Zoom and Trace' on page 42 of this Guide.

To change the size of a graph, do the following.

- Click anywhere in the graph to select it.
  The solid black box enclosing the graph region has three 'handles' (the small black squares at the bottom and right edges of the box).
- As you move the mouse arrow directly over a handle it will change into a double-headed arrow.
  Hold down the mouse button and drag in the direction you want to resize the graph.

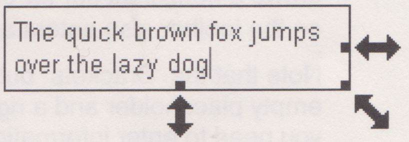


See Mathcad file 121A2-02, pages 4 and 5.

Related topics in this Guide : Graph scaling, page 38 ; Graphs – Zoom and Trace, page 42.

Resizing a text region

- Click anywhere in the text region to select it.
- Use the 'handles' to resize the text region. (See the technique for resizing a graph above for more details.)



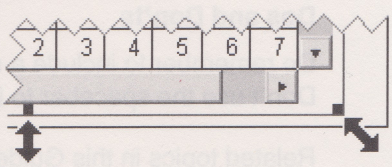
Note that changing the width of a text region may also change its height, (i.e. the number of lines required to display the text), but changing the height alone may have no effect on the text layout.

Related topic in this Guide : Entering text, page 21.

Resizing a (scrolling) table

When a table contains a lot of values, Mathcad switches automatically to a scrolling table (see page 29 of this Guide). However, it may be possible to view all the values without scrolling by resizing the table, i.e. by increasing its size to display more rows and / or columns.

- Click on a value in the table to select it.
- Use the 'handles' to resize the table. (See the technique for resizing a graph above for more details.)



See Mathcad files 221A1-01, page 5, and 221D2-02, page 2.

Numbers – Calculations

Basic mathematical operators

Calculations can involve numbers (Mathcad calls these *constants*), variables and functions. The standard functions, e.g. cos, sin, ln, exp, ..., are built into Mathcad ; see page 16 of this Guide.

To enter the basic operators in expressions, you can use the keyboard and / or the toolbar buttons.

◊ **Keyboard**

Type **+** , **−** , the asterisk ***** for multiply, the forward slash **/** for divide, and **^** for powers.

The decimal point is given by **.** (the full stop), and round brackets **(** and **)** , **[Shift]9** and **[Shift]0**, can be used to group terms within an expression.

You can use the keys on either the main keyboard, where ***** is given by **[Shift]8** and **^** is given by **[Shift]6**, or on the numeric keypad. (Note that **[Num Lock]** must be ON to use the numbers and operators on the numeric keypad. The word 'NUM' appears in the status bar in the bottom right corner of the Mathcad window when this is the case.)

◊ **'Calculator' toolbar buttons**

Click on [+] , [−] , [×] for multiply, [/] for divide, and [x^2] or [x^Y] for powers.

The decimal point is given by [.] , and round brackets by [( )] .

You should use the ' / ' button (pictured above) to enter a division in MST121 and MS221, as it draws a horizontal bar for division, which is the notation used in the course texts. (The ' ÷ ' button on the toolbar also enters a division, but it displays the division sign, e.g. 1 ÷ 2 = 0.5.)

Note that the 'Brackets' button inserts a pair of round brackets, i.e. a left bracket, followed by an empty placeholder and a right bracket. Entry continues in this placeholder, inside the brackets. If you need to enter information outside the brackets, then you may need to use the spacebar to extend the editing lines around the brackets before you can do so.

Multiplications in Mathcad

Entering a multiplication initially displays a small raised dot, but once Mathcad can identify what is being multiplied, it is able to display the multiplication in an appropriate form.

So Mathcad displays the multiplication sign x between two numbers, but doesn't display anything between two variables or a number and a variable, or before a bracket.

Examples $4 \times 7 = 28$ $\quad xy = 200$ $\quad 2x = 20$ $\quad 10(x + y) = 300$

Dos and Don'ts

Do remember to include a multiplication sign where appropriate, e.g. enter '**x*y**' not '**xy**'.
Don't use the spacebar to insert extra spaces in an expression. The spaces look after themselves !

Related topics in this Guide : Entering expressions, page 17 ; Toolbar buttons, page 57.

Calculation mode – automatic or manual

By default, Mathcad immediately (and automatically) calculates and updates all the results on the screen whenever values are entered or changed. This is **automatic mode**, and the word 'AUTO' is displayed in the status bar in the bottom right corner of the Mathcad window.

However, you can control calculations and changes to the screen display YOURSELF, by switching to **manual mode**.

- To put Mathcad into **manual** calculation mode, disable automatic mode by selecting the **Math** menu and choosing **Automatic Calculation**. The word 'AUTO' disappears from the status bar and is replaced by the words 'Calc F9'. (The tick mark beside Automatic Calculation in the menu also disappears.)

  Once in manual mode, you calculate and update each separate screen as and when you choose, either by selecting **Calculate** from the **Math** menu, or by pressing the [`F9`] function key. It is also possible to update all the results, calculating every screen, by selecting **Calculate Worksheet** from the **Math** menu.

You can switch from manual mode back to automatic mode at any time, simply select the **Math** menu and choose **Automatic Calculation** again.

See MST121 Computer Book B, Chapter B1, and MS221 Computer Book B, Chapter B1.

Interrupting calculations

Mathcad evaluates the expressions in a worksheet from left to right, going down a line at a time.

As Mathcad evaluates an expression, it encloses the expression within a green rectangle. Most calculations occur so rapidly that this rectangle appears and disappears in the twinkling of an eye, and you are not able to see it. However, the rectangle may be visible during a lengthy or complicated calculation. (The mouse arrow also changes into a flashing lightbulb when Mathcad needs time to complete a calculation.)

- To interrupt a calculation in progress, press [`Esc`], the Escape key.
  An option box appears ; click **OK** to stop the calculation, or **Cancel** to resume.

If you stop the calculation, then the expression that was being evaluated at the time is highlighted in red.

To complete this interrupted calculation later, first click on the expression (this reveals the 'Interrupted' error message pictured on the right), then choose **Calculate** from the **Math** menu or press the [`F9`] function key.

$$x_{i,n+1} := x_{i,n} + r_i \cdot x_{i,n} \cdot \left(1 - x_{i,n}\right)$$

You interrupted calculation. To resume, click here and choose "Calculate" from the "Math" menu.

Notes

You may need to **refresh** the screen after completing an interrupted calculation (see below).

If you find yourself frequently interrupting calculations to avoid having to wait for Mathcad to re-calculate as you edit your worksheet, then you may wish to switch to **manual** calculation mode. (See above.)

Refreshing the screen for an up-to-date view

When you are using Mathcad, the screen can sometimes become confused by unwanted bits and pieces of information. Also, expressions and pieces of text might appear to go missing.

You can **refresh** (re-draw) the screen, to obtain an up-to-date view of what is really there.

- Select the **View** menu, and choose **Refresh** or use the keyboard short-cut [`Ctrl`]`r`.

See Mathcad file 121A0-02, page 4.

Numbers – Displaying results and formatting

Displaying results

The values of arithmetic expressions and all types of variables and functions may be displayed by entering the equals sign at the end of the expression, either by typing = or by clicking on the ‘ = ’ button on the ‘Calculator’ toolbar. (To fit in the examples below, only the keyboard entry is shown.)

Type	**Mathcad example** Definition	Key sequence to display	Result displayed on the screen
Expression	$2+3$	`2+3=`	$2+3=5$
Variable	$A := 30$	`A=`	$A = 30$
Built-in variable	... already defined	`e=`	$e = 2.718$
Subscripted variable	$v_8 := 2$	`v[8=`	$v_8 = 2$
Sequence of subscripted variables	ORIGIN := 1 $n := 1,2..10$ $y_n := 1.1n + 1$	`y=` A **table of values** See page 29 for further details.	$y =$ (column header: 1) 1: 2.1 2: 3.2 3: 4.3 4: 5.4 5: 6.5 6: 7.6 7: 8.7 8: 9.8 9: 10.9 10: 12
Range variable	$k := 0,1..3$	`k=` `k^2=` **Tables of values** See page 30 for further details.	$k =$ 0, 1, 2, 3 $k^2 =$ 0, 1, 4, 9
Function values	$f(x) := 4x^2 - 56x + 192$	`f(3)=`	$f(3) = 60$
Built-in function	... already defined	`sin([Ctrl][Shift]p/2)=`	$\sin\left(\frac{\pi}{2}\right) = 1$

Tables of values – Displaying a sequence

A sequence of values, e.g. $y_1, y_2, y_3, \ldots$, can be displayed as a (scrolling) **table of values**.

- Type the name of the sequence, e.g. **y**

  immediately followed by typing = or clicking on the 'Calculator' toolbar button =.

The appearance of the table depends upon the number of values it contains. However, all the values in the sequence are displayed in each case.

◊ For sequences with nine values or less, Mathcad lists the values in order within round brackets. The first value in the sequence is shown at the top of the list.

◊ For sequences with ten or more values, Mathcad displays a recognisable table, with row and column headings.

◊ When the sequence has a lot of values, Mathcad provides a scrolling table. To access all the values, click once on a value in the table to reveal the scroll bar.

Examples

$$y = \begin{pmatrix} 2.1 \\ 3.2 \\ 4.3 \\ 5.4 \\ 6.5 \end{pmatrix}$$

y =

	1
1	2.1
2	3.2
3	4.3
4	5.4
5	6.5
6	7.6
7	8.7
8	9.8
9	10.9
10	12

y =

	1
1	2.1
2	3.2
3	4.3
4	5.4
5	6.5
6	7.6
7	8.7
8	9.8
9	10.9
10	12
11	13.1
12	14.2
13	15.3
14	16.4
15	17.5
16	18.6

! After using the scroll bar in a table of values, the table may be too narrow to see some of the new values fully. To reset the table to an appropriate width, click once on a value in the table and choose **Calculate** from the **Math** menu (alternatively, press the [F9] function key).

! The first value shown in a table will depend on the value of ORIGIN. (See page 15 of this Guide.) There are no problems when ORIGIN is set to 0 (the default value), but there can be problems when ORIGIN is set to 1. On some computers, a change is required to the worksheet calculation options for the correct first value to be shown. When ORIGIN is set to 1, it may be necessary to choose **Options...** from the **Math** menu, and then select the 'Calculation' tab and set the 'Performance Preferences' to **Backward Compatibility**.

Notes

A sequence can also be displayed as a (scrolling) table of values by using a range variable. For example, to display the sequence of values $y_1, y_2, \ldots, y_{10}$, you could define a suitable range variable, say n := 1, 2 .. 10, and then display y_n = . (See the next page for more details.)

Mathcad provides some formatting options for tables. To access the formatting options, you need to click on a value in the table with the *right* mouse button. This brings up a mini-menu, which includes **Properties...** (used to show or hide the row and column headings, or to alter the font) and **Alignment** (used to position the table in relation to the expression being evaluated).

See Mathcad files 121A1-01, page 5, 121A1-02, page 2, and 221A1-01, page 4.

Related topic in this Guide : Resizing a (scrolling) table, page 25.

Tables of values – Using a range variable

If you evaluate an expression involving a range variable then Mathad displays a (scrolling) **table of values**. The table displays the values taken by the expression as the range variable takes each value in its range.

By default, Mathcad displays the values in a long column, but when there are a lot of values it provides a scroll bar. To access all the values, click once on a value in the table to reveal the scroll bar. (See the previous page for more details.) Note that you may be able to resize the table, to see all the values without scrolling (see page 25 of this Guide) and that the formatting options (described at the top of this page) can be applied to the table.

Examples

Enter the expressions shown directly above each table,

then either type = or click on the 'Calculator' toolbar button = to display the table.

Display ranges $x := 0, 0.5 .. 6$ $n := 0, 1 .. 10$

$x =$	$f(x) =$
0	192
0.5	165
1	140
1.5	117
2	96
2.5	77
3	60
3.5	45
4	32
4.5	21
5	12
5.5	5
6	0

$n =$	$F_n =$	$\frac{\phi^n}{\sqrt{5}} =$
0	0	0.447
1	1	0.724
2	1	1.171
3	2	1.894
4	3	3.065
5	5	4.96
6	8	8.025
7	13	12.985
8	21	21.01
9	34	33.994
10	55	55.004

Notes

When using a range variable to display a sequence, the range can be chosen to view only a particular section of the sequence. The use of range variables also provides a quick and easy way to display the results of calculations involving sequences, for example displaying the difference or ratio between successive terms. (If the expression being evaluated is 'wider' than the table, then the equals sign may not be visible once the table is displayed.)

See Mathcad files 121A3-01, page 3, 221A1-01, page 5, and 221A1-02.

Related topics in this Guide : Range variables, page 14, Resizing a (scrolling) table, page 25.

Formatting results

To control how Mathcad displays the results of numerical calculations, you set the **result format**. You can set the default format, for every result in the worksheet, or an individual result format, for a particular calculation or table.

Default format

- Click in an empty space in the worksheet to obtain the red cross cursor.
- Select the **Format** menu and **Result...** .
  The 'Result Format' option box appears. (Any changes made now will apply throughout the worksheet. See below for details of how to make changes.)

Individual result format

- Click anywhere in the expression (a calculation or table involving '=') that you want to format.
- Select the **Format** menu and **Result...** .
  The 'Result Format' option box appears.

(Double-clicking on the result (to the right of the equals sign) will also bring up the option box.)

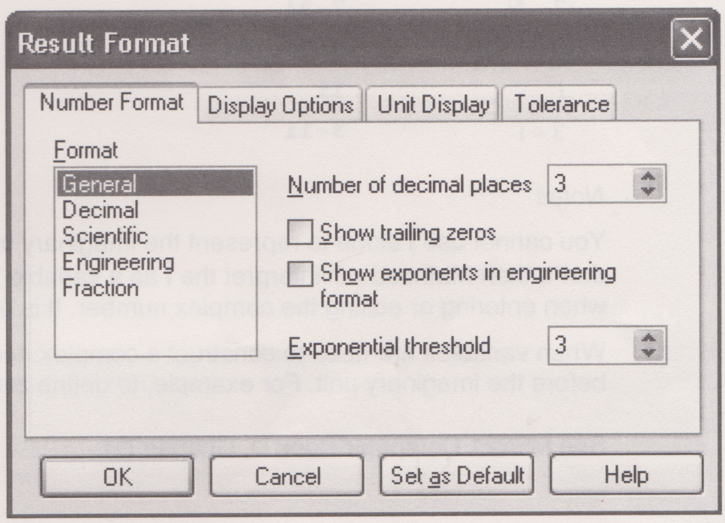
Settings in the 'Result Format' option box

The key settings in the 'Result Format' option box, are found on the 'Number Format' tab.

Make sure that 'General' is selected from the list of 'Format's, as shown here.

Notes

These settings affect only how results are displayed on the screen. Mathcad retains 15 significant figures internally for calculation purposes, independent of these settings.



◊ **Number of decimal places** (the default value is 3)
To set the number of decimal places, enter an integer *n* between 0 and 15.

◊ **Exponential threshold** (the default value is 3)
To set the exponential threshold, enter an integer *n* between 0 and 15.

Numbers of magnitude larger than 10^n (or less than 10^{-n+1}) are displayed in scientific notation. For example, when the threshold is 4 or less, the number 50 000 will be displayed as 5×10^4.

◊ **Show trailing zeros** (the default is OFF)

When 'trailing zeros' is ON, results are displayed with as many digits to the right of the decimal point as the setting for the number of decimal places. For example, if the number of decimal places is 3, then the number 6.1 will be displayed as 6.100.

See Mathcad files 121A0-03, page 4 and 121A1-05.

Numbers – Complex numbers

Creating complex numbers

Mathcad accepts complex numbers of the form **x + yi**, where **x** and **y** are real numbers. (There is NO multiplication sign between the '**y**' and the '**i**'.)

Examples	Key sequence
$1 + 2i$	**`1+2i`**
$7 - 5i$	**`7-5i`**
$0.2 + 0.9i$	**`0.2+0.9i`**
i	**`1i`**
$3 - i$	**`3-1i`**

You can also use the 'Calculator' toolbar.

For example, click the buttons [1] [+] [2] [i]

Notes

You cannot use **i** alone to represent the imaginary unit. Instead, you must always type `1i` (if you don't, then Mathcad will interpret the **i** as a variable). The extra '1' in front of the **i** is visible only when entering or editing the complex number. It is hidden from view once the number is complete.

When variables are used to construct a complex number, you MUST include a multiplication sign before the imaginary unit. For example, to define z as a + bi, you could type **`z:a+b*1i`** .

See MS221 Computer Book D, Chapter D1.

Arithmetic with complex numbers

The basic mathematical operators **+** , **-** , ***** , **/** and **^** can all be used with complex numbers.

Examples – Define $z := 3 + 4i$ and $w := 1 + 2i$

Evaluate $z = 3 + 4i$ $\quad w = 1 + 2i$

$z + w = 4 + 6i$ $\quad z - w = 2 + 2i$ $\quad z\,w = -5 + 10i$

$\frac{1}{z} = 0.12 - 0.16i$ $\quad \frac{z}{w} = 2.2 - 0.4i$ $\quad z^2 = -7 + 24i$

Notes

When operating on complex numbers directly, you must enclose them within brackets.

For example $(3 + 4i)(1 + 2i) = -5 + 10i$

Expressions that involve only real numbers may also produce a complex value, e.g. $\sqrt{-1} = i$

Finding real and imaginary parts, complex conjugates and polar form

Mathcad provides some built-in functions and operators for working with complex numbers.

Real and imaginary parts

Function			Example $z := 3 + 4i$
Re(z)	Real part of a complex number.	Type **`Re(z)=`**	$\mathrm{Re}(z) = 3$
Im(z)	Imaginary part of a complex number.	Type **`Im(z)=`**	$\mathrm{Im}(z) = 4$

Notes

Function names are case-sensitive in Mathcad.
You must type the capital letters ‘R’ and ‘I’ to begin the function names ‘Re’ and ‘Im’.

Complex conjugates

To find the complex conjugate of a complex number.

- ♦ Enter the expression, and then select the entire expression.
  (If necessary, click on it and press [**`Space`**] until the blue editing lines enclose it all.)
- ♦ Type a double-quote **"** (given by [**`Shift`**]**`2`**) to obtain the complex conjugate operator.
- ♦ Finally, either type **=** or click on the ‘ = ’ button to evaluate the expression.

Example $z := 3 + 4i$ Type **`z"=`** $\boxed{z}$ ➡ $\boxed{\overline{z}}$ ➡ $\boxed{\overline{z} = 3 - 4i}$ ➡ $\overline{z} = 3 - 4i$

If you want to find the complex conjugate of a complex number directly, remember to select the entire expression first. (In the example below, Mathcad adds the brackets around 1 + 2i itself !)

Example $1 + 2i$ ➡ $\boxed{1 + 2i}$ ➡ $\boxed{\overline{(1 + 2i)}}$ ➡ $\boxed{\overline{(1 + 2i)} = 1 - 2i}$ ➡ $\overline{(1 + 2i)} = 1 - 2i$

Polar form of complex numbers – modulus and argument

To find the polar form **< r, θ >** of a complex number.

Modulus

- ♦ Click on the |x| button on the ‘Calculator’ toolbar
  or type a vertical bar | (given by [**`Shift`**]**`\`**).
- ♦ Enter the expression, followed by **=** to evaluate the modulus, **r**.

Example $z := 3 + 4i$
Type **`|z=`** $|z| = 5$

Argument

- ♦ Use the function **`arg(z)`** to find the argument **θ**, in radians.
  (Mathcad returns an angle between $-\pi$ and π.)

Type **`arg(z)=`** $\arg(z) = 0.927$

Exponential form of complex numbers

Example – Define $r := \sqrt{2}$ and $\theta := \dfrac{\pi}{4}$

$z := r\,e^{i\theta}$ You could type **`z:r*e^1i*q[Ctrl]g`** or use the ‘Calculator’ and ‘Greek’ toolbar buttons.

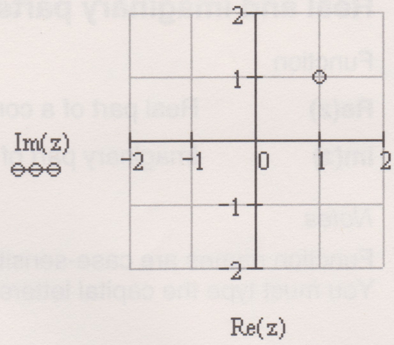
Evaluate $z = 1 + i$

Remember to enter the imaginary unit as **`1i`**, and to include the multiplication between ‘i’ and ‘θ’.
(For more information about entering Greek letters in expressions, see page 18 of this Guide.)

Drawing an Argand diagram

To represent a complex number **z** in Cartesian form z = a + bi on an Argand diagram.

Example $z := 1 + i$



- Simply create a standard **X-Y graph** (see page 35) and plot the point (**Re(z)**, **Im(z)**).
- Format the graph, setting the trace symbol to something visible, e.g. **o's**. (See page 41.)
  The diagram can be enhanced by adding grid lines and / or axes, and scaling and resizing the graph.

Note that a complex number in polar form z = < r, θ > can be displayed on a polar plot.

See MS221 Computer Book D, Chapter D1, and Mathcad file 221D1-01.

Related topics in this Guide : Adding graph axes, page 37 ;
Graph scaling, page 38 ; Resizing a graph, page 25.

Complex number solutions to equations

Both the symbolic keyword **solve** (see page 48) and the **polyroots** function (see page 44) will return ALL the roots of a polynomial equation at once, whether real or complex.

The examples below illustrate finding the roots of **$z^3 = 1$**.

Symbolic keyword **solve**

$$z^3 = 1 \text{ solve}, z \rightarrow \begin{pmatrix} 1 \\ \frac{-1}{2} + \frac{1}{2} i \times 3^{\frac{1}{2}} \\ \frac{-1}{2} - \frac{1}{2} i \times 3^{\frac{1}{2}} \end{pmatrix}$$

polyroots

Solve the equation $\mathbf{a_0 + a_1 z + a_2 z^2 + a_3 z^3 = 0}$

Define coefficients $a_0 := -1 \quad a_1 := 0 \quad a_2 := 0 \quad a_3 := 1$

Solution ... $\text{polyroots}(a) = \begin{pmatrix} -0.5 - 0.866i \\ -0.5 + 0.866i \\ 1 \end{pmatrix}$

Notes

The **polyroots** function will always return numerical values, while the symbolic keyword **solve** returns the roots in symbolic form, e.g. expressions involving fractions and square roots.

See MS221 Computer Book D, Chapter D1, and Mathcad file 221D1-02.

Related topic in this Guide : Solving equations, page 43.

Graphs – Drawing

How to create an X-Y graph

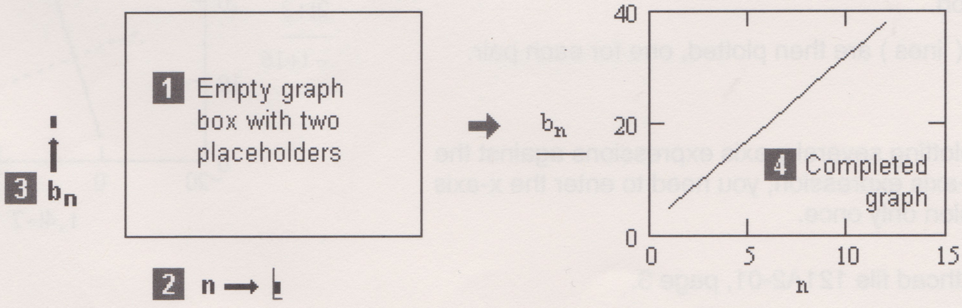
The same basic graph procedure is used to plot a **sequence** (see Mathcad file 121A1-01), a **curve described by parametric equations** (file 121A2-01), and a **function** (file 121A3-01).

Graphs are constructed with the use of range variables. (See page 14 of this Guide.)

Mathcad will plot one point for each value of the range variable used in the graph. So, prior to creating the graph itself, you must define a suitable range variable. This variable should then appear in the x-axis and y-axis expressions used to plot the graph.

- ♦ Position the red cross cursor where you want the top left corner of the graph to be drawn.
- ♦ Click on the 'X-Y Plot' button on the 'Graph' toolbar.
  Alternatively, select the **Insert** menu, **Graph ▶ X-Y Plot**, or type @ (given by [`Shift`]`'`).
- ♦ Mathcad creates a large black selection box, and inside this, an empty graph box [1].
  Enter the expression to plot on the x-axis into the placeholder on the horizontal axis [2].
  (Mathcad pre-selects this placeholder, ready for you to use.)
- ♦ Next enter the y-axis expression into the placeholder on the vertical axis [3].
  (To select this placeholder, either click on it with the mouse or press the [`Tab`] key twice.)
- ♦ Finally, click anywhere outside the graph region, or press [`Enter`].
  Mathcad will calculate and plot the points [4].

In the example below, a range variable **n** is used to plot a **sequence** : the points (**n**, $\mathbf{b_n}$).



By default, Mathcad draws a line graph (see Graphs – Formatting, page 39) and automatically scales the graph axes (see Graph scaling, page 38).

Exactly the same technique (described on the previous page) is used to plot :

◊ a **parametric curve**, e.g. the points (**cos(t)** , **sin(t)**) with a graph range variable **t** ;

◊ a **function**, e.g. the points (**x**, **f(x)**) with a range variable **x**.

Notes

When you enter an expression into the placeholder on the x-axis, two further placeholders appear, at each end of the x-axis. You can enter values into these placeholders to fix the x-axis limits. Similarly, when you enter an expression into the placeholder on the y-axis, two further placeholders appear for the y-axis limits. (If you leave these placeholders blank, then Mathcad automatically scales the graph axes – see Graph scaling, page 38.)

There is a quick way to construct a graph by combining everything in one instruction :

y-axis expression ; create graph ; **x**-axis expression.

For example, type `b[n@n`, then press [`Enter`] to plot the points (**n**, $\mathbf{b_n}$) !

Mathcad also provides an even more rapid 'QuickPlot' facility that can be used to plot a function, *without* the need to first define a range variable, or the need to enter an x-axis expression :

y-axis expression ; create graph .

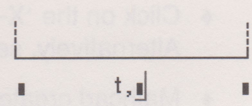
For example, type `f(x)@`, then press [`Enter`] to plot the points (**x**, **f(x)**) !
(Here the function f(x) has been defined previously in the worksheet, but *not* the variable x.)

Mathcad automatically produces a plot of the function over the range –10 to 10. You can change this range by changing the limits on the x-axis (see Graph scaling, page 38).

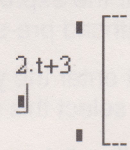
Plotting two (or more) curves on the same graph

To plot several curves on the same graph, enter the expressions for 'x' separated by **commas** on the x-axis, and likewise the 'y' expressions on the y-axis.

- Follow the standard procedure to create a graph. (See page 35.)
- Enter the first **x**-axis expression, followed by a **comma**.
  A second placeholder appears just to the right.
  Enter the second **x**-axis expression here, and so on.

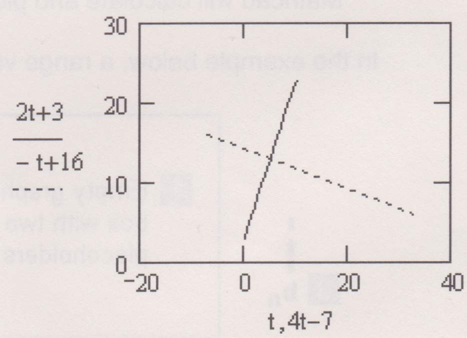


- Select the placeholder in the middle of the **y**-axis.
- After typing the first **y**-axis expression followed by a **comma**, a second placeholder appears immediately below, ready for the second expression, and so on.



Mathcad matches up the expressions in pairs.
The first x-axis expression is plotted against the first y-axis expression, and the second against the second, and so on.

Traces (lines) are then plotted, one for each pair.



Notes

When plotting several y-axis expressions against the same x-axis expression, you need to enter the x-axis expression only once.

See Mathcad file 121A2-01, page 3.

Related topics in this Guide : Adding graph axes, page 37 ; Trace settings, page 40.

Adding graph axes

Mathcad does NOT draw lines for the graph axes automatically – you must add these yourself.

Two ways to do this are described below, and another two ways are available by formatting the graph, so that **Grid Lines** are ON or the **Axis Style** is **Crossed** (see pages 39 and 40).

Plotting extra lines on a graph

- **x-axis** (the line y = 0)
  Define a suitable graph range **x**, and plot the points (**x**, **0**), i.e. put **x** in the placeholder on the horizontal axis, and **0** in the placeholder on the vertical axis.
- **y-axis** (the line x = 0)
  Define a suitable graph range **y**, and plot the points (**0**, **y**).

There is no need to use variables called **x** and **y** here. Indeed, if the x- and y-axes have the same scale, then you can define a single graph range, say **s**, and plot the points (**s**, **0**) and (**0**, **s**).

Example

Plotting a function and adding both the x- and y-axes.

Enter `x,0,x` on the horizontal axis and `0,y,f(x)` on the vertical axis.

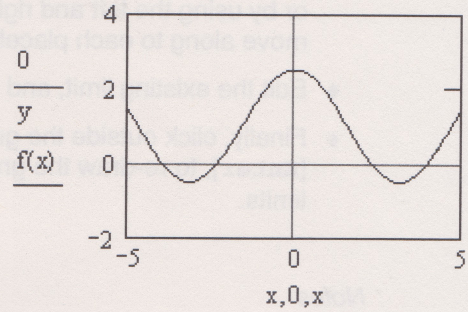
The lines drawn for the axes can be formatted to any colour and style. (See page 40.)

See also Mathcad file 221A2-02, page 3.

Related topic in this Guide :
Plotting two (or more) curves on the same graph, page 36.

Graph ranges

x := −5,−4.9..5 y := −2,−1.9..4



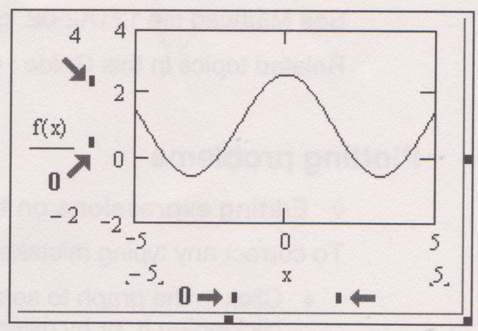
Formatting a graph using Show Markers

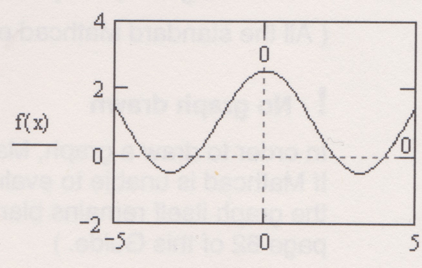
- Click in the graph to select it. (Graph surrounded by a black selection box.)
- Choose **Graph ▶ X-Y Plot...** from the **Format** menu.
  Turn **Show Markers** ON. (See page 39 for more details about graph formatting.)

  Two extra placeholders appear on each axis.
- Click on one of these placeholders, and enter a number.
  (Pressing [`Tab`] will then select the next placeholder.)

  For the **x**-axis,
  enter **0** in one of the placeholders on the **vertical** axis.

  For the **y**-axis,
  enter **0** in one of the placeholders on the **horizontal** axis.
- Finally, click outside the graph region, or press [`Enter`], to produce two dotted red marker lines for the axes.





Notes

The format of these marker lines cannot be changed, and Mathcad also labels them with their values.

See Mathcad file 121A1-02, page 2.

Graph scaling

◊ **Mathcad automatically sets the graph scale** (the default)

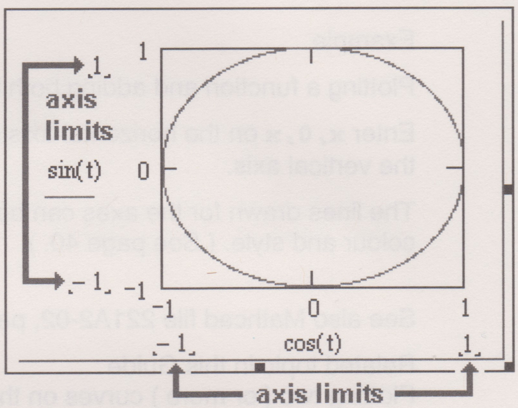
By default, Mathcad chooses a 'nice' round number for each of the axis limits, ensuring that all the graph data is displayed within the graph box. If this data changes, then Mathcad automatically rescales the graph axes. (This situation is 'Autoscale' ON, see Graphs – Formatting, page 39.)

You can format the graph and turn 'Autoscale' OFF. If you do this, Mathcad still scales and rescales the graph automatically, but now sets the axis limits to the extreme values of the data, i.e. the traces plotted on the graph always extend to the edges of the graph box.

◊ **Fixing your own graph scale**

You can fix the scale by entering values for the axis limits into the four placeholders at the ends of the axes. This can be done either when the graph is first created (when the graph box and all the placeholders are empty) or after the graph has been drawn – the situation shown below.

- Click in the graph to select it.
  (Graph surrounded by a black selection box.)
- Select an axis limit either by clicking on it, or by using the left and right arrow keys to move along to each placeholder in turn.
- Edit the existing limit, and enter your new value.
- Finally, click outside the graph region, or press [`Enter`], to re-draw the graph with the new axis limits.



Notes

You can fix the value for one, two, three or all four of the axis limits.

To remove a fixed scale and let Mathcad automatically set the limits again, simply delete the existing limit value to leave an empty placeholder.

Mathcad may add or subtract tick marks or grid lines after rescaling.

See Mathcad file 121A2-02, page 4.

Related topics in this Guide : Graphs – Zoom and Trace, page 42 ; Resizing a graph, page 25.

Plotting problems

◊ **Editing expressions on the graph axes**

To correct any typing mistakes, change the expressions plotted or alter the graph scale.

- Click in the graph to select it, then select the expression you wish to change either by clicking on it, or by using the left and right arrow keys to move along each expression in turn.

(All the standard Mathcad editing techniques can be applied – see page 19 of this Guide.)

! No graph drawn

In order to draw a graph, Mathcad must be able to evaluate the expressions on the x- and y-axes. If Mathcad is unable to evaluate one of the expressions, then it highlights the expression in red and the graph itself remains blank. (Clicking on this 'red' expression will reveal an error message – see page 62 of this Guide.)

Suggested action – try a different graph range.

See MST121 Computer Book A, Chapter A3.

! ‘Missing lines’

A graph trace can be hidden under the edge of the graph box or by another trace.
Alternatively, the data you are plotting may lie outside the chosen graph scale.

Suggested actions – try formatting the graph trace to mark the individual points with a symbol (see below) or alter the graph scale (page 38).

! Scale and size

Care is needed in interpreting what you see.

If the scales on the two axes are not identical, then the curves drawn will be distorted due to different scalings in the two directions. For example, a circle may appear elliptical.

See Mathcad file 121A2-02, pages 4 and 5.

Related topics in this Guide : Graph scaling, page 38 ; Resizing a graph, page 25.

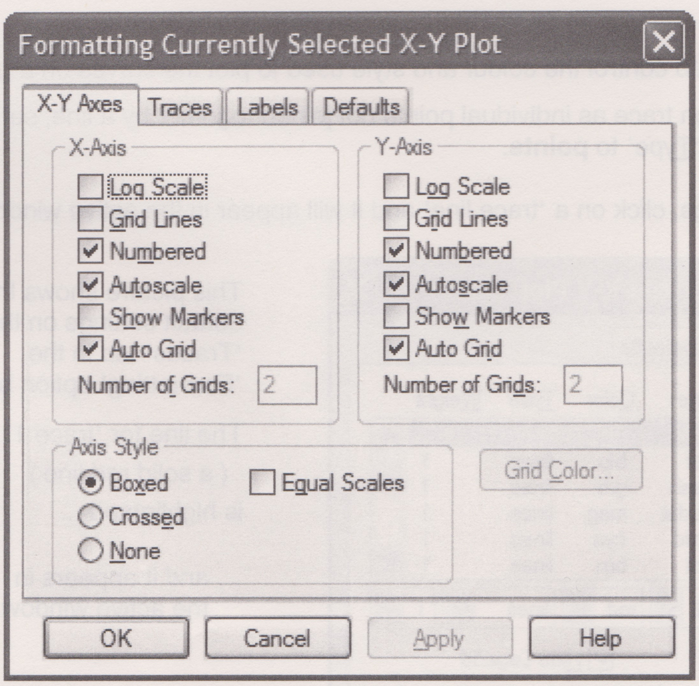
Graphs – Formatting

- Click in the graph to select it. (Graph surrounded by a black selection box.)
- Choose **Graph** ► **X-Y Plot...** from the **Format** menu.
  Alternatively, double-click in the middle of the graph itself.

  This brings up the option box titled ‘Formatting Currently Selected X-Y Plot’.
- Change the desired settings in the option box (see the next two pages for details) then click on the large **OK** button to see the results.

See Mathcad file 121A1-01, pages 7 and 8.

Axis settings



This picture shows the default settings on the ‘X-Y Axes’ tab in the ‘Formatting’ option box.

Log Scale	OFF
Grid Lines	OFF
Numbered	ON
Autoscale	ON
Show Markers	OFF
Auto Grid	ON
Axis Style	Boxed

(Details are on the next page.)

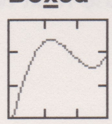
The effects of turning the axis options ON (ticked) or OFF are shown in the table below.
Note that they are shown in *alphabetical* order, and are set independently for the x- and y-axes.

For example, to display 10 grid lines on an axis :
turn ‘Grid Lines’ ON ; ‘Auto Grid’ OFF and set the ‘Number of Grids’ to 10.

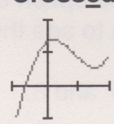
Axis setting		**Effect**
Auto Grid	ON	Mathcad selects the number of tick marks (or grid lines).
	OFF	You choose the number of tick marks (or grid lines). Set the ‘Number of Grids’ from 2 to 99.
Autoscale	ON	Mathcad sets the axis limits to ‘nice’ round numbers.
	OFF	Mathcad sets the axis limits to the extremes of the data.
Grid Lines	ON	Displays grid lines in place of tick marks. (By default, the grid lines are green. You can use the ‘Grid Color...’ button to change the colour.)
	OFF	Displays tick marks rather than grid lines.
Log Scale	ON	Axis is transformed to a logarithmic scale.
Numbered	ON	Numbers the tick marks (or grid lines) on the axis.
Show Markers	ON	Adds reference lines to the plot. See ‘Adding graph axes’ on page 37 of this Guide.

At the bottom of the ‘X-Y Axes’ tab you can set the **Axis Style**

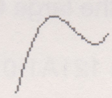
Boxed



Crossed



None

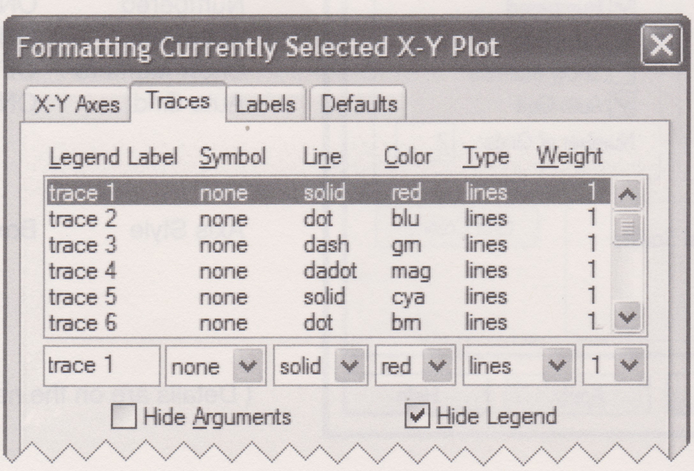


Trace settings

The settings on the ‘Traces’ tab control the colour and style used to plot the curves on a graph.

For example, to display a graph trace as individual points not joined together by a line, set the trace ‘Symbol’ to **x’s** and the ‘Type’ to **points**.

♦ To change the trace settings, click on a ‘trace line’ and it will appear in the active window.



This picture shows the default settings on the ‘Traces’ tab in the ‘Formatting’ option box.

The line for ‘trace 1’ (a solid red line) is highlighted ...

... and it appears in the active window.

◊ **Legend Label**

The name of the curve can be changed by clicking on the current name, e.g. 'trace 1' in the active window. Type in the new name to be given to the curve. (The trace name is displayed on the graph only if **Hide Legend** is OFF – see below.)

To change the other trace settings in the active window, click on the small down arrow in the column that you want to change, and select from the drop-down list which appears. (The trace will be re-drawn using these settings once all the graph formatting is complete, i.e. when you click **OK**.)

◊ **Symbol**

Plot symbols : **none** ; **x's** ; **+'s** ; **box** ; **dmnd** (diamond) ; **o's.**

◊ **Line**

Line style : **solid** ; **dot** ; **dash** ; **dadot** (dash-dot).

◊ **Color** (Note that Mathcad uses American spelling)

Trace colour : **red** ; **blu** (blue) ; **grn** (green) ; **mag** (magenta, i.e. purple) ;
cya (cyan, i.e. light blue) ; **brn** (brown) ; **blk** (black) ; **wht** (white).

◊ **Type**

Trace type : **lines** ; **points** ; **error** ; **bar** ; **step** ; **draw** ; **stem** ; **solidbar**.

◊ **Weight**

The weight (line thickness and / or symbol size) ranges from **1** (thin / small) to **9** (thick / large). There is a special weight **p** at the bottom of the list, which attempts to draw the thinnest curve and smallest symbol possible on your computer system. (It may be no different from weight 1.)

The two other options on the 'Traces' tab control the display of axis labels and legends.

◊ **Hide Arguments** (Default OFF, i.e. the arguments are shown – *not* hidden !)

When this is ON, Mathcad hides the expressions on the axes used to plot the graph. This can be useful where the expressions would otherwise take up too much space.

See Mathcad files 121B2-03, pages 3 and 4, and 221B1-01, page 2.

◊ **Hide Legend** (Default ON, i.e. the legend is *not* shown – hidden !)

When this is OFF, Mathcad displays a legend (key) for the traces plotted on the graph.

Label settings

The settings on the 'Labels' tab can be used to add a title or axis labels to your graph.

See Mathcad file 121B2-02, pages 3 and 4.

Default settings for the graph format

When you create an X-Y graph, it automatically gets the default graph format.
For example, by default Mathcad draws a line graph with the first trace as a solid red line.

If you intend to create many similar graphs in a worksheet, you can set the default format to match.

♦ Create the first graph as usual, then resize and format it to your desired style. Then click in the check box labelled **Use for Defaults** on the 'Defaults' tab in the 'Formatting' option box.

Each new graph will then be drawn using the size and format you specified for the first graph.

Graphs – Zoom and Trace

Zooming in on a graph

There are five steps to follow to zoom in and magnify a *portion* of a graph.

- Click in the graph to select it. (Graph surrounded by a black selection box.)
- Click on the 'Zoom' button on the 'Graph' toolbar or select **Graph ► Zoom...** from the **Format** menu.

  The 'X-Y Zoom' option box appears. If the option box is covering part of your graph, then you can move it.

- Click the mouse at the bottom left corner [1] of the area you want to magnify. Then drag the mouse arrow to the top right corner [2]. Release the mouse button.

  The coordinates of the vertices of the selected area are listed in the 'Min:' and 'Max:' boxes in the option box.

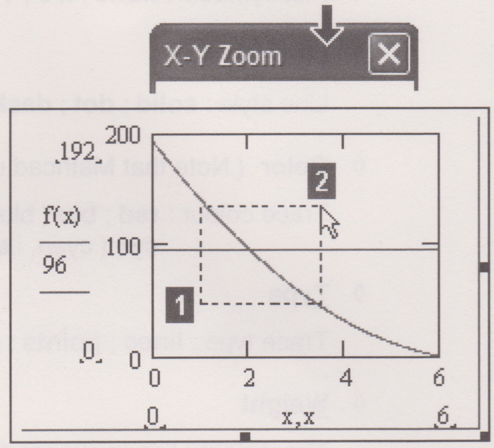
- Click on the **Zoom** button to plot the selected area.

  You can repeat the two steps above to zoom in further.

- To finish zooming and to make the new axis limits permanent, click on the **OK** button.

  (Clicking **Full View** will revert to the original graph.)

Click and drag to move the box



See Mathcad file 121A3-01, page 5.

Related topics in this Guide : Resizing a graph, page 25 ; Graphical solution, page 44.

Trace – obtaining a readout of graph coordinates

The trace facility is used to identify the coordinates of points on a graph.
(It can be used on its own or in conjunction with the graph zoom option above.)

- Click in the graph to select it. (Graph surrounded by a black selection box.)
- Click on the 'Trace' button on the 'Graph' toolbar or select **Graph ► Trace...** from the **Format** menu.

  The 'X-Y Trace' option box appears. If the option box is covering part of your graph, then you can move it.

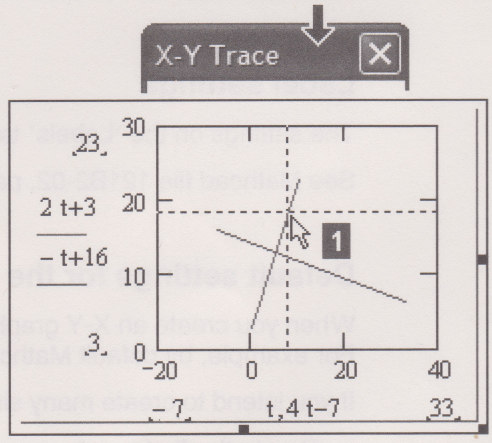
- Click and drag the mouse arrow [1] in the graph box.

  A dotted crosshair follows your mouse pointer, and Mathcad displays the coordinates of the pointer in the 'X-Value' and 'Y-Value' boxes in the option box.

  By default, the crosshair 'hops' along the data points plotted on the graph. To move anywhere within the graph, click to remove the tick for 'Track Data Points'.

- To finish, click on the **Close** button, and click outside the graph region to remove the selection box.

Click and drag to move the box



See Mathcad file 121A2-01, page 4.

Related topic in this Guide : Graphical solution, page 44.

Solving equations

How to construct equations and inequalities

	Button	Keystroke	Description
x = y	=	`[Ctrl]=`	Equation ~ left- and right-hand sides equal
x ≥ y	≥	`[Ctrl]0`	Greater than or equal to
x ≤ y	≤	`[Ctrl]9`	Less than or equal to
x > y	>	`>` (`[Shift].`)	Greater than
x < y	<	`<` (`[Shift],`)	Less than

Notes – All the buttons shown above are on the 'Boolean' toolbar.

Examples		Entry sequence
Equation	$4x^2 - 56x + 192 = 96$	Click on = 9 6 or type `[Ctrl]= 96`
Constraint	$0 \le x$	Click on 0 ≤ or type `0 [Ctrl]9` , then type `x`

The solve block

The solve block is a numerical method for solving a system of equations. Mathcad '**Find**'s and displays a value of the unknown that solves the '**Given**' equations and constraints.

A block is set up as follows.

Step …			
	1	Make a reasonable guess.	$x := 1$
	2	Use the Mathcad keyword **Given**.	Given
	3a	Give the equation(s).	$4x^2 - 56x + 192 = 96$
	3b	Give the constraint(s).	$0 \le x$ $x \le 6$
	4	Use the Mathcad function **Find** to obtain and display the answer.	Find(x) = 2

Notes

The keyword Given is a (black) Mathcad expression, not (blue) Mathcad text.

Mathcad looks for a solution until the error in the answer obtained is less than or equal to the built-in variable TOL (see page 15 of this Guide). Where a system of equations and constraints has more than one solution, the answer obtained may depend on the initial guess. It is also possible that a solve block fails to find an answer – this is indicated by the error message ‘No solution was found’.

Instead of ending the block with Find(x)= you can make a variable definition like a := Find(x). The value of the solution (contained in a) can then be used elsewhere in the worksheet.

See Mathcad files 121A3-02, pages 2 and 3, and 221B1-03, pages 2 and 3.

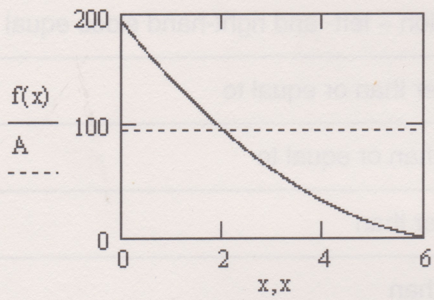
Graphical solution

Solving the equation **f(x) = A** corresponds to finding where the horizontal line **y = A** meets the graph of **y = f(x)** . By repeatedly zooming into the graph (see page 42 of this Guide) you should be able to identify the x-value of the point of intersection.

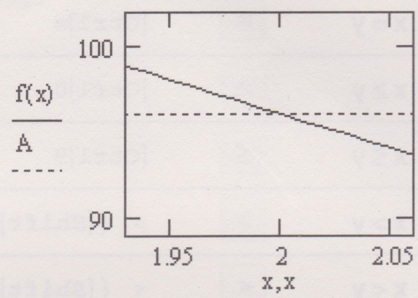
Example

Function ... $f(x) := 4x^2 - 56x + 192$

Target value $A := 96$ Graph range $x := 0, 0.01 .. 6$



Graph after repeated **zooming** ...
the intersection occurs when **x = 2** .



Notes – The step size used to plot the graph may limit the accuracy of the solution you can obtain.

See Mathcad file 121A3-01, pages 5 and 6.

Related topic in this Guide : Graphs – Drawing, page 35.

How to use polyroots

polyroots is a built-in Mathcad function which finds the solutions to a polynomial equation.
It solves equations of the form $a_0 + a_1x + a_2x^2 + a_3x^3 + ... + a_nx^n = 0$.

- The first step is to construct a vector, **a**, whose elements are the coefficients of the polynomial : $a_0, a_1, ..., a_n$.
  To do this, either create the vector directly (see page 50 of this Guide), or define a subscripted variable for each element individually (see pages 13 and 34).
- The expression **polyroots(a)** then gives all the solutions to the polynomial equation.

  Unlike the solve block method, **polyroots** does not require an initial guess. Moreover, it returns numerical values for all the solutions at once, whether real or complex.

  Example :
  solve the equation
  $1 + 2x - 3x^2 + 2x^3 = 0$.

  Define $a := \begin{pmatrix} 1 \\ 2 \\ -3 \\ 2 \end{pmatrix}$ Solve $\text{polyroots}(a) = \begin{pmatrix} -0.317 \\ 0.909 + 0.867i \\ 0.909 - 0.867i \end{pmatrix}$

  Type `polyroots(a)=`

See Mathcad file 221D1-02 and MS221 Computer Book D, Chapter D1.

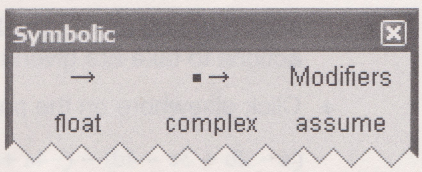
Related topic in this Guide : Complex number solutions to equations, page 34.

Symbolic calculations

Preparing to work symbolically

The Mathcad tools for symbolic calculations (for manipulating letters as well as numbers algebraically) can be accessed either by clicking on the buttons on the ‘Symbolic’ toolbar or by typing the keyboard alternatives.

- If you want to open the ‘Symbolic’ toolbar, then either click on the button on the ‘Math’ toolbar, or select the **View** menu, **Toolbars** and **Symbolic**.



Notes

The Symbolics item on the menu bar contains the symbolic calculation options found in earlier versions of Mathcad – this menu is *not* used in MST121 or MS221.

Evaluating an expression symbolically (‘ → ’)

- Make sure that the blue editing lines are within the expression [1].
(If necessary, click on the expression – the editing lines can be placed anywhere.)
- Click on the ‘Symbolic Evaluation’ button → on the ‘Symbolic’ toolbar [2].
(The keyboard alternative is `[Ctrl].` , i.e. hold down the control key and type a full stop.)
- Click elsewhere on the page or press `[Enter]` to evaluate the expression [3].

1 $\int_{-1}^{1} \sqrt{1-x^2}\,dx$ ➡ **2** $\int_{-1}^{1} \sqrt{1-x^2}\,dx \rightarrow$ ➡ **3** $\int_{-1}^{1} \sqrt{1-x^2}\,dx \rightarrow \frac{1}{2}\cdot\pi$

The symbolic equals sign ‘ → ’ gives an exact answer, e.g. an expression involving fractions,

constants such as π, and square roots. It evaluates expressions in a comparable way to how the ordinary equals sign ' = ' evaluates numerical expressions. The result of a symbolic evaluation is updated automatically if you change the expression on the left-hand side of the symbolic equals sign ' → '.

Related topics in this Guide : Differentiating symbolically, page 52 ; Integrating symbolically, page 54.

How to apply a symbolic keyword

Mathcad provides a range of keywords (e.g. 'simplify', 'expand', 'factor', 'solve', 'series') which can be added to the symbolic equals sign ' → ' to perform particular mathematical operations.

- Position the vertical blue editing line at the end of the expression.

  $\boxed{(a - 2\cdot b + 3\cdot c - 4\cdot d) - (-4\cdot a + 3\cdot b - 2\cdot c + d)}$ (The horizontal editing line can be any length.)

  As you enter an expression the vertical editing line is usually at its right-hand end. So, on competing the entry, the vertical editing line should already be in position. However, if this isn't the case, then you can position the vertical editing line as follows.

  Click anywhere on the expression and then press the spacebar [**Space**] repeatedly, to extend the editing lines until they select it all. The vertical editing line may already be at the right-hand end of the expression, which is as required. If the vertical line is at the left-hand end then press the [**Insert**] key, which will make the line switch ends. (On some computers this key is just labelled [**Ins**].)

- Click on the keyword button, e.g. simplify , on the 'Symbolic' toolbar.
  (Alternatively, press [**Ctrl**][**Shift**]**.** , i.e. hold down the control and shift keys and type a full stop, then release these keys and type the keyword, e.g. **simplify**.)

  $\boxed{+ 3\cdot b - 2\cdot c + d)}$ ➡ $\boxed{(a - 2\cdot b + 3\cdot c - 4\cdot d) - (-4\cdot a + 3\cdot b - 2\cdot c + d)\ \text{simplify} \rightarrow}$

  Note that additional placeholders may appear after the keyword at this stage. Details of what actions to take are given in the Guide sections on the individual keywords which follow.

- Click elsewhere on the page or press [**Enter**] to see the result.

  $(a - 2b + 3c - 4d) - (-4a + 3b - 2c + d)\ \text{simplify} \rightarrow 5a - 5b + 5c - 5d$

Notes

Several symbolic keywords can be applied to an expression by chaining them together.
The example below shows the keywords 'simplify' and 'factor' chained together horizontally.

$$10x^2 + 4\left(3x - x^2\right)\ \text{simplify} \rightarrow 6x^2 + 12x\ \text{factor} \rightarrow 6x(x + 2)$$

The first keyword is applied to the expression in the usual way, then the second keyword is added by applying it to the result produced by the first keyword, and so on. (In the example above, you need to position the vertical editing line at the right-hand end of the result produced by 'simplify', i.e. after the ' + 12x ', before you enter 'factor'.)

It is also possible to chain symbolic keywords together vertically.

$$10x^2 + 4\left(3x - x^2\right)\ \left|\begin{array}{l}\text{simplify}\\ \text{factor}\end{array}\right. \rightarrow 6x(x + 2)$$

To add a second keyword vertically, you need to position the vertical editing line at the right-hand end of the first symbolic keyword (i.e. just before the ' → '), before you enter the second keyword.

Note that chaining the symbolic keywords together horizontally displays the intermediate results from each step, while chaining together vertically displays only the final result.

Expanding an expression ('expand,x →')

- To **expand** (multiply out) an expression, apply the symbolic keyword 'expand', using the procedure described on the previous page.

  You can click on the [expand] button on the 'Symbolic' toolbar,

  or type **[Ctrl][Shift].expand**

If you click on the button, then an empty placeholder appears after the keyword – enter the name(s) of the variable(s) in the expression. (If there is more than one variable, separate the names with commas.) In the example below you would type **x**, to expand in powers of x.

$(x+1)\cdot(x-2)$ ➡ $(x+1)\cdot(x-2)$ expand,▪ → ➡ $(x+1)\cdot(x-2)$ expand,x →

Note that no placeholder appears if you use the keyboard entry method, so you must type a comma to obtain one, followed by the variable name, e.g. type **,x** .

Completed example $\quad (x+1)(x-2)$ expand,x $\rightarrow x^2 - x - 2$

See Mathcad file 121A0-05, page 3.

Expanding an expression to a series ('series,x = a,n+1 →')

- To calculate the **Taylor series** expansion for an expression, apply the symbolic keyword 'series', using the procedure described on the previous page.

  You can click on the [series] button on the 'Symbolic' toolbar,

  or type **[Ctrl][Shift].series**

If you click on the button, then two empty placeholders appear after the keyword. In the left-hand placeholder, enter the name of the variable in the expression, followed by Mathcad's special equals ' = ' (see page 43 of this Guide) and the point about which you're finding the series. In the right-hand placeholder (which Mathcad selects first !), enter the number of terms required. To display the Taylor series up to the term in x^n, you should enter the value $n+1$.

sin(x) ➡ sin(x) series,▪,▪ → ➡ sin(x) series,x = 0,8 →

Note that no placeholders appear if you use the keyboard entry method, so you must type commas to obtain them, e.g. type **,x[Ctrl]=0,8** .

Completed example $\quad \sin(x)$ series,x = 0,8 $\rightarrow 1x - \frac{1}{6}x^3 + \frac{1}{120}x^5 - \frac{1}{5040}x^7$

Notes

If you just enter the name of the variable and no value for the number of terms, e.g. series,x , then Mathcad will display the Taylor series about x = 0, of order 6, i.e. up to the term in x^5.

See Mathcad file 221C3-01, page 2.

Factorising an expression ('factor →')

- To **factorise** an expression, apply the symbolic keyword 'factor', using the procedure described on the previous page.

  You can click on the [factor] button on the 'Symbolic' toolbar,

  or type **[Ctrl][Shift].factor**

If you click on the button, then an unwanted empty placeholder appears after the keyword.

You should delete this placeholder by pressing the [**Backspace**] key twice, as shown below.

Press [**Backspace**] Press [**Backspace**]

$a^2 \cdot b - a \cdot b^2$ factor, | → ➡ $a^2 \cdot b - a \cdot b^2$ factor □ | → ➡ $a^2 \cdot b - a \cdot b^2$ factor| →

Note that no placeholder appears if you use keyboard entry, so there is nothing to delete !

Completed example $a^2 b - a b^2$ factor $\rightarrow a b (a - b)$

See Mathcad file 121A0-05, pages 4 and 5.

Simplifying an expression ('simplify →')

- To **simplify** an expression, apply the symbolic keyword 'simplify', using the procedure described on page 46.

  You can click on the simplify button on the 'Symbolic' toolbar,

  or type [**Ctrl**][**Shift**]**.simplify**

Example $(a - 2b + 3c - 4d) - (-4a + 3b - 2c + d)$ simplify $\rightarrow 5a - 5b + 5c - 5d$

See Mathcad file 121A0-05, page 2.

Solving equations symbolically ('solve,x →')

- To **solve** an equation, apply the symbolic keyword 'solve', using the procedure described on page 46.

  You can click on the solve button on the 'Symbolic' toolbar,

  or type [**Ctrl**][**Shift**]**.solve**

If you click on the button, then an empty placeholder appears after the keyword – enter the name of the variable in the expression you wish to solve for.

$4 \cdot x^2 - 56 \cdot x + 96 = 0$| ➡ $4 \cdot x^2 - 56 \cdot x + 96 = 0$ solve, | → ➡ $4 \cdot x^2 - 56 \cdot x + 96 = 0$ solve, x| →

Note that no placeholder appears if you use the keyboard entry method, so you must type a comma to obtain one, followed by the variable name, e.g. type **,x** .

Completed example $4x^2 - 56x + 96 = 0$ solve, x $\rightarrow \begin{pmatrix} 2 \\ 12 \end{pmatrix}$

The example above illustrates Mathcad's way of showing two solutions : x = 2 and x = 12.

Notes

The special equals ' = ' for the equation can be entered by clicking on the = button on the 'Boolean' toolbar or by typing [**Ctrl**]=. (See page 43 of this Guide.)

The 'solve' keyword can be used on expressions which don't contain an equals sign ! Mathcad assumes that the expression containing the variable is equal to zero in such cases.

See Mathcad file 121A3-03.

Related topic in this Guide : Solving equations, page 43.

How to obtain decimal results for symbolic calculations

When calculating symbolically, Mathcad gives an exact answer. For example, the result may contain fractions, constants such as π, and square roots. To obtain such a result in decimal form, you can evaluate it *numerically*.

- Place the blue editing lines within the result of the symbolic calculation. (If necessary, click on the expression for the result – the editing lines can be placed anywhere.)
- Click on the 'Calculator' toolbar button [=] or type = .
- Click elsewhere on the page or press [**Enter**] to finish.

Example $\quad 4x^2 - 56x + 192 = 144 \text{ solve},x \rightarrow \begin{pmatrix} 7 + 37^{\frac{1}{2}} \\ 7 - 37^{\frac{1}{2}} \end{pmatrix} = \begin{pmatrix} 13.083 \\ 0.917 \end{pmatrix}$

(The number of decimal places displayed is determined by the result format – see page 31.)

Alternatively, you can force Mathcad to give a decimal answer by editing the original expression so that it includes a decimal point somewhere (e.g. change 144 to 144.0). Doing this triggers up to **20** digits in the result, irrespective of the result format used within the worksheet !

Example $\quad 4x^2 - 56x + 192 = 144.0 \text{ solve},x \rightarrow \begin{pmatrix} .91723746970178031100 \\ 13.082762530298219689 \end{pmatrix}$

See Mathcad file 121A3-03.

How to define a function as the result of a symbolic calculation

In the example shown, the function Df(x), the derivative of f, is defined as the result of a symbolic calculation. The expression for Df may look a little daunting, but it can be broken down into more manageable chunks.

Function ...... $f(x) := x^3 - 2x - 2$

Derivative f'(x) $\quad Df(x) := \frac{d}{dx}f(x) \rightarrow 3x^2 - 2$

It consists of a standard function definition for Df(x), the Mathcad expression for the derivative, and a symbolic evaluation '$\rightarrow$' and symbolic result. It is this result which becomes the right-hand side of the definition for Df(x) – if any change is made to f, then Df will change too.

Problems when working symbolically

Mathcad gives a variety of responses if it is not able to carry out a symbolic calculation. In some situations (e.g. if unable to simplify an expression), it will just return the original expression as the answer. Alternatively, it may highlight the expression in red, and clicking on this will reveal an error message (e.g. 'No solution found', if Mathcad is unable to solve an equation).

Note that symbolic calculations can be controlled in the same way as numerical ones in Mathcad. If you find yourself waiting a long time for any response, then you can interrupt the calculation by pressing [**Esc**], the escape key. You can also use manual mode. (See page 27 of this Guide.)

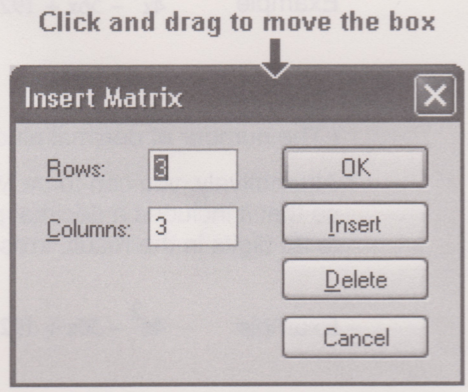
Note too, that if a variable has been defined in the worksheet, then subsequent symbolic calculations will use its numerical value, not its name, e.g. x. If you wish to use the name, then you can tell Mathcad to ignore the prior definition, by defining the variable as itself, e.g. $x := x$.

Mathcad uses the numerical value of x $\quad x := 3 \quad \frac{d}{dx}\left(\frac{x^2}{5}\right) \rightarrow \frac{6}{5}$

Now Mathcad uses the symbol x $\quad x := x \quad \frac{d}{dx}\left(\frac{x^2}{5}\right) \rightarrow \frac{2}{5}x$

Matrices and vectors

How to create a matrix (or vector)



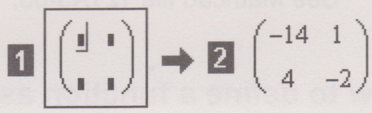
- Click on the 'Matrix or Vector' button on the 'Matrix' toolbar. Alternatively, select the **Insert** menu and **Matrix...**, or type [Ctrl]m.

  The 'Insert Matrix' option box appears. If necessary, move the option box to a convenient spot on the screen.

- Enter the number of rows and columns you require, then click on the **OK** button. (The 'Insert' button is used to insert extra rows and columns into an existing matrix.)

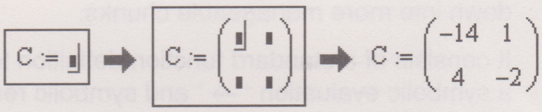
  Mathcad creates a blank matrix with the appropriate number of empty placeholders. The placeholder in the top left corner is selected [1].

- Fill in this first placeholder, then select the others either by clicking directly on them or by using the [Tab] key, which goes along the placeholders in each row in turn [2].



Matrices may be created either in a blank space in a worksheet (at the position marked by the red cross cursor) or in an empty placeholder within an expression.

For example, to assign a matrix to a variable, do the following. Define a variable, say **C**, and select the placeholder at the right-hand side of the definition. Then follow the procedure above to create the matrix.



Notes

A matrix created in this way can have a maximum of 100 elements, e.g. 10 rows x 10 columns.

Remember that a *vector* is a one-column matrix !

See Mathcad file 121B2-01, page 2.

How to edit a matrix

- Click on the matrix element you wish to change. You can use the left and right arrow keys to position the blue editing lines as required. (Pressing these keys will also move around the matrix elements in turn.)
- Rub out with the [Backspace] key or the [Delete] key as required, and enter the new value.
- Click elsewhere on the page or press [Enter] to finish.

Related topic in this Guide : Editing expressions : controlling the editing lines, page 19.

Labelling and displaying matrices and their elements

The way in which Mathcad displays a matrix depends upon its size (the number of rows and columns). Small matrices, with less than 10 rows and 10 columns, are shown using round brackets, while large matrices are shown as (scrolling) tables of values ; see page 29 of this Guide for further details.

To display a matrix, type the matrix name,

then click on the [=] button or type =, e.g. type **C=** and **v=** $\quad C = \begin{pmatrix} -14 & 1 \\ 4 & -2 \end{pmatrix} \quad v = \begin{pmatrix} 5 \\ -7 \\ 19 \end{pmatrix}$

Matrix elements

Subscript notation is used to refer to the individual elements of a matrix.

Examples of matrix and vector elements $\quad C = \begin{pmatrix} -14 & 1 \\ 4 & -2 \end{pmatrix} \quad C_{0,0} = -14 \quad C_{0,1} = 1 \quad C_{1,0} = 4 \quad C_{1,1} = -2 \quad v = \begin{pmatrix} 5 \\ -7 \\ 19 \end{pmatrix} \quad v_0 = 5 \quad v_1 = -7 \quad v_2 = 19$

To obtain the subscripts, either use the 'Subscript' [X_n] button on the 'Matrix' toolbar

or type **[** (left square bracket), e.g. type **C[0,0=** $\quad C_{0,0} = -14$

Note that Mathcad uses the value of ORIGIN to label the first row and first column of a matrix. So with ORIGIN set as **0** (which is its default value), Mathcad refers to the top left element of the matrix as $\mathbf{C_{0,0}}$. If you change ORIGIN to 1, then Mathcad refers to this element as $\mathbf{C_{1,1}}$.

Related topic in this Guide : ORIGIN, page 15.

Matrix columns

The superscript operator $^{<>}$ (toolbar button [$M^{<>}$] or type **[Ctrl]6**) extracts a column from a matrix.

Example $\quad Q = \begin{pmatrix} 7 & 12 & -8 \\ 8 & 3 & 1 \end{pmatrix} \quad Q^{\langle 0 \rangle} = \begin{pmatrix} 7 \\ 8 \end{pmatrix} \quad Q^{\langle 1 \rangle} = \begin{pmatrix} 12 \\ 3 \end{pmatrix} \quad Q^{\langle 2 \rangle} = \begin{pmatrix} -8 \\ 1 \end{pmatrix}$

Note that Mathcad uses the value of ORIGIN to label the first column.

See Mathcad file 221D3-02, page 4.

Matrix operations (including inverses and determinants)

The standard Mathcad mathematical operators **+**, **-**, ***** (multiply) and **^** (powers) can all be used with matrices. In particular, raising a matrix to the power **-1** gives the matrix inverse, where it exists.

- To find the inverse, use the 'Inverse' button [X^{-1}] on the 'Matrix' toolbar or type **^-1**.
- To calculate the determinant, use the [|x|] button, or type **[Shift]** (shift and backslash). (This button is available on the 'Calculator' toolbar as well as the 'Matrix' toolbar.)

Examples $\quad A = \begin{pmatrix} 2 & 0 \\ 3 & 1 \end{pmatrix} \quad$ Inverse $\quad A^{-1} = \begin{pmatrix} 0.5 & 0 \\ -1.5 & 1 \end{pmatrix} \quad$ Determinant $\quad |A| = 2$

Notes – Applying the '|x|' operator to a vector gives the magnitude of the vector.

See Mathcad file 121B2-01, page 3, and MST121 Computer Book B, Chapter B2.

Differentiation and integration

Evaluating the derivative at a point

- First, define the point at which the derivative is to be found.
- Click on the 'Derivative' button $\frac{d}{dx}$ on the 'Calculus' toolbar or type **?** (a question mark, given by [`Shift`]**/**).
  The d/dx operator appears [1].
- Enter the differentiation variable in the left-hand placeholder, then select the other placeholder and enter the expression to be differentiated. Make sure that the expression is enclosed in brackets, to tell Mathcad to differentiate all of it [2].
- Click on the = button on the 'Calculator' toolbar or type = [3].
  (Make sure that the blue editing lines are somewhere within the expression when you do this.)
- Click elsewhere on the page or press [`Enter`] to finish [4].

Point $x := 3$ **1** $\frac{d}{d\blacksquare}\blacksquare$ → **2** $\frac{d}{dx}\blacksquare$ → $\frac{d}{dx}\left(\frac{x^2}{5}\right)$ → **3** $\frac{d}{dx}\left(\frac{x^2}{5}\right) = 1.2$ → **4** $\frac{d}{dx}\left(\frac{x^2}{5}\right) = 1.2$

Notes

Once a value has been defined for the differentiation variable, then evaluating Mathcad's d/dx operator symbolically will also give the value of the derivative at that particular point (see below).

You can enter the name of a function (which has been defined previously) into the derivative operator.

Function $f(x) := \frac{x^2}{5}$ Point $x := 3$ $\frac{d}{dx}f(x) = 1.2$

When evaluating a derivative numerically, Mathcad uses a numerical algorithm to obtain an approximation to the exact value of the derivative at that point. The answer obtained is usually accurate to 7 or 8 significant figures. (The accuracy does not depend on the value of the built-in variable TOL.) If this numerical method fails to produce an answer, then the derivative is highlighted in red, and clicking on it reveals the error message 'Can't converge to a solution'.

See Mathcad file 121C1-01 and MST121 Computer Book C, Chapter C1.

Differentiating symbolically (Finding a formula for the derivative)

- Click on the 'Derivative' button $\frac{d}{dx}$ on the 'Calculus' toolbar or type **?** (a question mark, given by [`Shift`]**/**).

  The d/dx operator appears [1].

- Enter the differentiation variable in the left-hand placeholder, then select the other placeholder and enter the expression to be differentiated. Make sure that the expression is enclosed in brackets, to tell Mathcad to differentiate all of it [2].

- Click on the [→] button on the 'Symbolic' toolbar or type **[Ctrl].** [3].
  (Make sure that the blue editing lines are somewhere within the expression when you do this.)

- Click elsewhere on the page or press **[Enter]** to display the derivative [4].

1 $\frac{d}{d\blacksquare}\blacksquare$ ➡ **2** $\frac{d}{dx}\blacksquare$ ➡ $\frac{d}{dx}\left(\frac{x^2}{5}\right)$ ➡ **3** $\frac{d}{dx}\left(\frac{x^2}{5}\right) \rightarrow$ ➡ **4** $\frac{d}{dx}\left(\frac{x^2}{5}\right) \rightarrow \frac{2}{5}x$

! If the differentiation variable has been defined previously in the worksheet (e.g. $x := 3$), then this procedure will give the value of the derivative at that particular point, not a general formula. (See 'Problems when working symbolically' on page 49.)

Notes – You can find a formula for the derivative of a named function (which has been defined previously), e.g. $f(x) := \frac{x^2}{5}$ $\quad \frac{d}{dx}f(x) \rightarrow \frac{2}{5}x$

See Mathcad file 121C1-01 and MST121 Computer Book C, Chapter C1.

Related topic in this Guide : Evaluating an expression symbolically, page 45.

Higher-order derivatives

- Click on the 'Nth Derivative' button [$\frac{d^n}{dx^n}$] on the 'Calculus' toolbar or type **[Ctrl]?** (you need to press **[Ctrl]**, **[Shift]** and **/**).

  The higher-order derivative operator appears. $\quad \frac{d^{\blacksquare}}{d\blacksquare^{\blacksquare}}\blacksquare$

- Fill in the placeholders for the expression and differentiation variable. Use the lower remaining placeholder to set the order of the derivative (2, 3, 4 or 5). The top placeholder is automatically filled with the value typed in the lower one. $\quad \frac{d^2}{dt^2}\left(t^3 + t^2\right)$

- Evaluate the higher-order derivative numerically or symbolically, as required.

Examples $\quad$ Point $\; t := 1 \quad \frac{d^2}{dt^2}\left(t^3 + t^2\right) = 8 \qquad \frac{d^2}{dx^2}\left(x^3 + x^2\right) \rightarrow 6x + 2$

Evaluating a definite integral numerically

- Enter the definite integral in the same way as for symbolic evaluation. (See the next page.)
- Make sure that the blue editing lines are somewhere within the integral,

  then click on the [=] button on the 'Calculator' toolbar or type = to evaluate it.

- Click elsewhere on the page or press **[Enter]** to finish.

Examples $\quad \int_2^3 \frac{1}{x}\,dx = 0.405 \qquad$ Function $\; f(x) := \frac{1}{x} \qquad \int_2^3 f(x)\,dx = 0.405$

Notes

Mathcad uses a numerical algorithm to evaluate the integral. The accuracy of the answer obtained depends on the built-in variable TOL (see page 15). While the value of TOL does not indicate the

accuracy directly, reducing TOL should increase the accuracy. If this numerical method fails to produce an answer, then the integral is highlighted in red, and clicking on it reveals the error message 'Can't converge to a solution'.

See MST121 Computer Book C, Chapter C2.

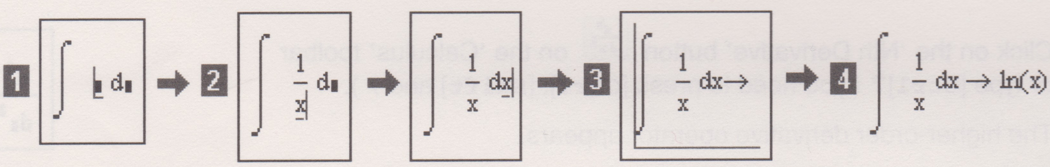
Integrating symbolically (Indefinite and definite integrals)

Both **indefinite** and **definite integrals** can be evaluated symbolically. Mathcad finds a formula for an integral of the supplied expression or function, and then for the definite integral, subtracts its value at the lower integration limit from its value at the upper limit. If Mathcad cannot find a formula, then it is unable to evaluate the integral. (When this occurs, Mathcad may highlight the integral in red and give an error, or repeat the original integral as the 'answer'.)

See MST121 Computer Book C, Chapter C2.

Indefinite integral – Evaluate symbolically

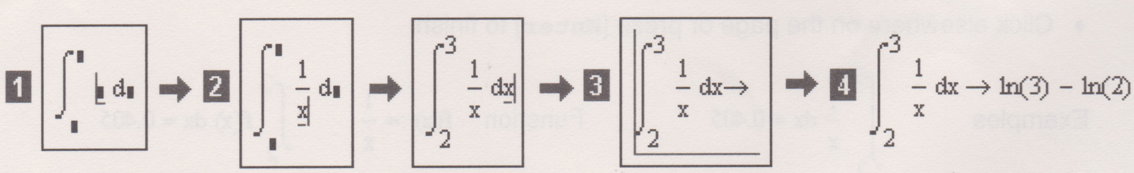
- Click on the 'Indefinite Integral' button on the 'Calculus' toolbar or type **[Ctrl]i** .
  The integral sign appears with two empty placeholders [1].
- Enter the expression (or function name) to be integrated and the integration variable [2].
- Click on the → button on the 'Symbolic' toolbar or type **[Ctrl].** [3].
  (Make sure that the blue editing lines are somewhere within the expression when you do this.)
- Click elsewhere on the page or press **[Enter]** to finish [4].



Notes – Mathcad gives only *an* integral of the supplied expression.
It does NOT include an arbitrary constant of integration ' *c* ' in the answer.

Definite integral – Evaluate symbolically

- Click on the 'Definite Integral' button on the 'Calculus' toolbar or type **&** (an ampersand, given by **[Shift]7**).
  The integral sign appears with four empty placeholders [1].
- Enter the expression to be integrated, the integration limits and the integration variable [2].
- Click on the → button on the 'Symbolic' toolbar or type **[Ctrl].** [3].
  (Make sure that the blue editing lines are somewhere within the expression when you do this.)
- Click elsewhere on the page or press **[Enter]** to finish [4].



Notes – You can evaluate the definite integral of a named function (which has been defined previously), e.g. $f(x) := \frac{1}{x} \quad \int_2^3 f(x)\,dx \rightarrow \ln(3) - \ln(2)$

Menu bar commands

File Edit View Insert Format Math Symbolics Window Help

The following list of menu bar commands is arranged in *alphabetical* order.

It describes the commands most frequently used in MST121 and MS221 together with their keyboard short-cuts, but it does not list every Mathcad menu command.

Note that all the page references in this section are to pages in this Guide.

Edit menu

Copy	`[Ctrl]c`	Copy selected expression, graph or text.
Cut	`[Ctrl]x`	Delete selected expression, graph or text.
Go to Page...		Move through a worksheet to the top of a specified page. (See page 9.)
Paste	`[Ctrl]v`	Paste selection most recently copied or cut. The selection can be inserted either at the position of the red cross cursor or in an empty placeholder in an expression.
Undo	`[Ctrl]z`	Undo the most recent change when editing a mathematical expression or piece of text.

File menu

Close	`[Ctrl]w`	Close the current worksheet.
Exit	`[Alt][F4]`	Quit Mathcad !
New	`[Ctrl]n`	Create a new, empty worksheet.
Open...	`[Ctrl]o`	Open an existing Mathcad file from disk.
Print...	`[Ctrl]p`	Print entire worksheet or particular pages. (See page 10.)
Save As...		Save current worksheet using a new file name.
Save	`[Ctrl]s`	Save current worksheet. **!** This command overwrites an existing file with the same name on the disk with NO further prompting.

Format menu

Equation...		Change the default font and / or colour used to display mathematical expressions. (See page 9.)
Graph ►	**Trace...**	Identify the coordinates of a point on a graph. (See page 42 and Mathcad file 121A2-01.)
	X-Y Plot...	Set the display format for the selected X-Y graph. (See page 39.)
	Zoom...	Select and magnify a portion of an X-Y graph. (See page 42 and Mathcad file 121A3-01.)
Result...		Set the display format for the results of numerical calculations. (See page 31.)
Style...		Change the default font and / or colour used to display text, or format text using a built-in style. (See pages 8 and 23.)

Help menu

Note that this help is provided by the makers of Mathcad ; it is NOT specific to the course.

Mathcad Help	`[F1]`	Details of Mathcad features and procedures, with search facilities for a particular topic. (See page 59.)
Resource Center		Display the 'Resource Center' window. (See page 60.)
Tip of the Day...		Show tips about how to use Mathcad. (See page 60.)

Insert menu

Function...	`[Ctrl]e`	Display a scrolling list of Mathcad's built-in functions from which you can select. (See page 16.)
Graph ► X-Y Plot...		Create an empty graph box ready for a plot. (See page 35.) The keyboard short-cut is the 'At' sign, @ , given by `[Shift]'`.
Matrix...	`[Ctrl]m`	Create a matrix. (See page 50 and Mathcad file 121B2-01.)
Page Break		Insert a hard pagebreak. (See page 10.)
Text Region	`[Shift]2`	Create a new text region at the red cross cursor position. The keyboard short-cut is a double-quote, ". (See page 21.)

Math menu

Automatic Calculation		Switch between automatic and manual calculation modes. (See page 27.)
Calculate	`[F9]`	Manually update all the results visible on the screen. (See page 27.)
Calculate Worksheet		Manually update all the results in the worksheet.

Symbolics menu

This menu is *not* used in MST121 or MS221 – it contains the symbolic calculation options found in earlier versions of Mathcad. See 'Symbolic calculations' on page 45 for details of the options that *are* used in the course – which are accessed via the 'Symbolic' toolbar or the keyboard.

View menu

Refresh	`[Ctrl]r`	Refresh (re-draw) the screen to tidy it up. (See page 27.)
Toolbars		Show or hide the various Mathcad toolbars. (See page 57.)
Zoom...		Show a magnified or reduced view of the entire worksheet. (See page 10.)

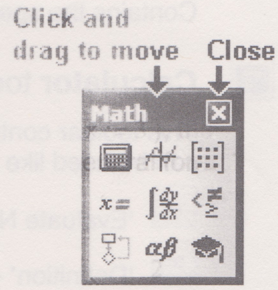
Window menu

If you have more than one worksheet open, then you can use this menu to switch between them or to arrange them side by side on the screen.

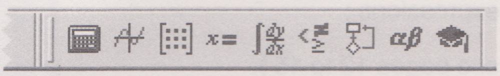
Toolbar buttons

Mathcad provides several toolbars, which contain button alternatives for menu commands, and for entry of mathematical operators and symbols. You can show or hide each toolbar individually by using the **View** menu, and **Toolbars**, which reveals the toolbar menu. Selecting a toolbar name on this menu switches between open (indicated by a tick next to the name), when the toolbar is visible, and closed (the toolbar is hidden).

When you open a toolbar, it 'floats' above the worksheet, and can be dragged (click anywhere on the toolbar other than a button) around the screen to a convenient location. (You can also click on the close box in the top right-hand corner of the toolbar to close it.)

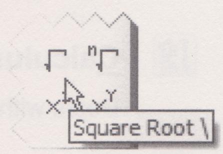


If you drag the toolbar to the top of the Mathcad window, underneath the menu bar, then the toolbar buttons are displayed in a horizontal strip.



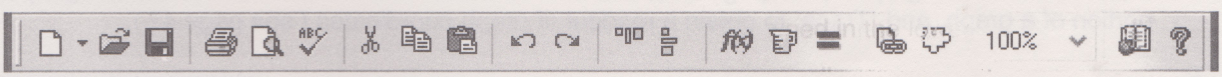
(Dragging the toolbar to the left or right edge of the window will give a vertical strip of buttons.)

If you leave the mouse arrow over a toolbar button then after a little while a 'tooltip' appears, giving the name of the button, followed usually by the keyboard alternative. For example, to enter a square root, you could click on the button (on the 'Calculator' toolbar) or type \ (the backslash key). Also, buttons that are equivalent to menu commands are pictured on the menus.



You can have any number of toolbars open at once. Note that Mathcad 'remembers' the location of ALL open toolbars when you exit. So the next time that you start up Mathcad, any toolbars that were open when you exited will be reopened automatically, in exactly the same places as you left them.

Standard toolbar



The 'Standard' toolbar appears by default, just below the menu bar, and it contains button alternatives to some standard *Windows* menu items.

For example, starting from the left-hand end of the toolbar, the first four buttons relate to worksheet management : New ; Open ; Save ; Print. (See pages 10 and 11 of this Guide.)

Formatting toolbar

The 'Formatting' toolbar appears by default, immediately below the 'Standard' toolbar.
It contains scrolling lists and buttons used to format text. (See page 23 of this Guide.)

Math toolbar

The 'Math' toolbar (pictured at the top of this page) contains buttons that can used to open the nine mathematical toolbars, described on the next page.

To open / close the 'Math' toolbar, select the **View** menu, **Toolbars** ► **Math**.

See Mathcad file 121A0-04, page 2.

Mathematical toolbars

There are nine mathematical toolbars, which can be accessed via the buttons on the 'Math' toolbar or by using the **View** menu. For example, to open the 'Calculator' toolbar, click on the appropriate button on the 'Math' toolbar (pictured below), or select the **View** menu, **Toolbars** ► **Calculator**.

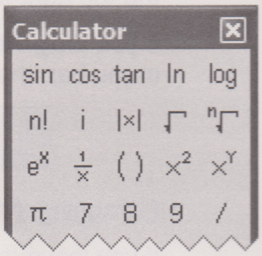
Note that the toolbars are listed below in *alphabetical* order, and that all the page references in this section are to pages in this Guide.

Boolean toolbar

Contains the special equals sign for use in equations and symbols for inequalities. (See page 43.)

Calculator toolbar

This toolbar contains numbers and common arithmetic operators, and can be used like a pocket calculator. It also contains the important buttons :



= 'Evaluate Numerically' – to evaluate expressions ;

:= 'Definition' – to define expressions (see pages 12 to 15).

See Mathcad file 121A0-04, page 2, and 121A3-01, page 2.

Calculus toolbar

Deals with differentiation and integration, as well as summation. (See pages 52 to 54.)

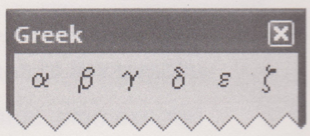
Evaluation toolbar

Contains equals sign buttons for evaluation and definition.
(The 'Evaluate Numerically' and 'Definition' buttons also appear on the 'Calculator' toolbar.)

Graph toolbar

Used to create X-Y graphs (see page 35), and also contains the tools to 'Zoom' in and magnify a portion of a graph, and 'Trace' to obtain a readout of graph coordinates (see page 42).

Greek toolbar



Contains a button for each Greek letter, to enter in expressions or text.
(See page 18.)

Matrix toolbar

Contains buttons for creating a subscripted variable (see page 13), a range variable (page 14) and matrices and vectors (page 50). There are also buttons for some matrix operations, such as inverse and determinant (page 51).

Programming toolbar

This toolbar enables the construction of simple programs, further extending what Mathcad can do. In MS221 Block D, programs are used to implement a few numerical algorithms, but you do not need to follow the details or use this facility yourself.

Symbolic toolbar

For symbolic evaluation and symbolic keywords. (See pages 45 to 49.)

Note that the 'Modifier' toolbar, which appears as a separate item on the toolbar menu, is included as a button on the 'Symbolic' toolbar.

Mathcad Help, Resource Center and Tip of the Day

Mathcad provides a range of on-screen help facilities, which are available via the **Help** menu.

! Please note

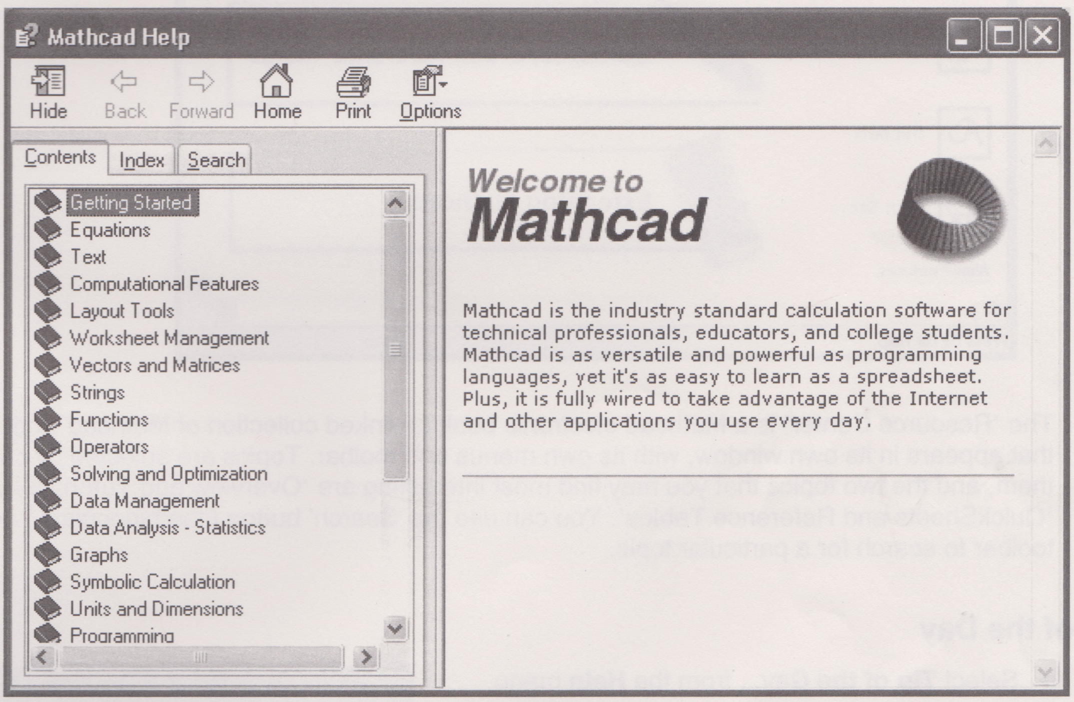
This help is provided by the makers of Mathcad ; it is NOT specific to the course.

If you need help during a Mathcad session, then we recommend that you look first within the course worksheet and associated Computer Book, where detailed Mathcad instructions, hints and explanations may be provided for the task in hand. Your next source of help should be this Guide, which IS specific to MST121 and MS221.

Mathcad Help

- To get help, select **Mathcad Help** from the **Help** menu.
  (Alternatively, press the [F1] function key.)

  This brings up the 'Mathcad Help' window, shown below.



Choose the 'Contents' tab for details about basic Mathcad procedures. Note that you need to double-click on a 'book' entry to open it, then a single click will suffice to view an item within it.

The 'Index' and 'Search' tabs can be used to search for particular information. Both search methods act on the keyword you type in, with 'Index' matching your keyword alphabetically to an entry in the index of help topics, and 'Search' returning all topics that include your keyword.

Notes

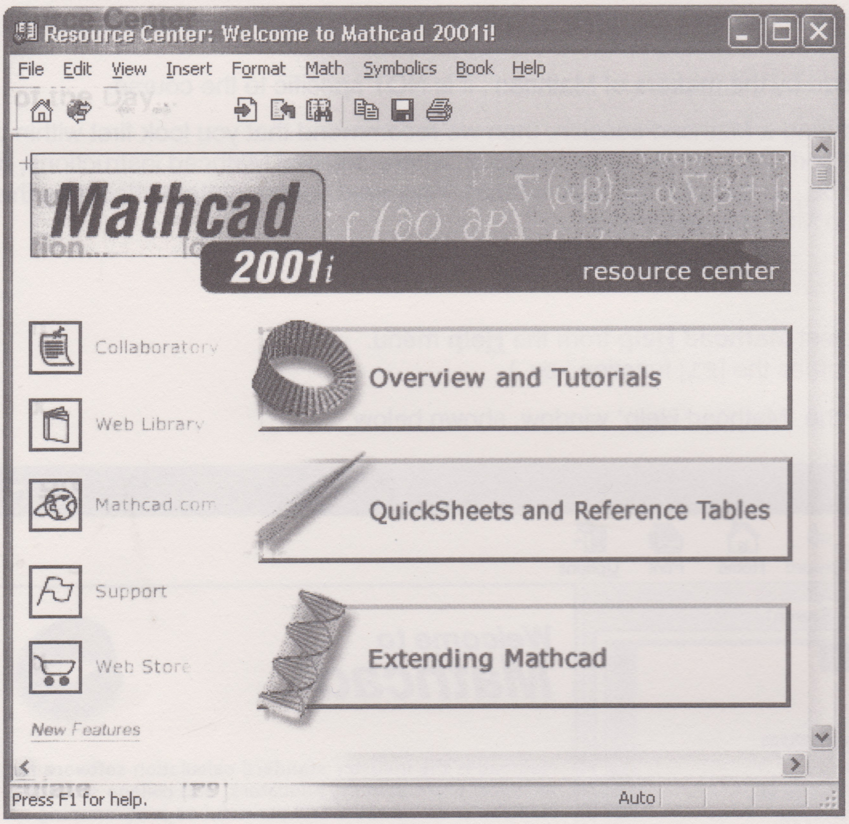
If an error occurs in an expression (i.e. the expression is highlighted in red), then clicking on it and selecting this help option will display information about the error in the 'Mathcad Help' window.

Some pages of information are displayed in the 'Mathcad Help' window using facilities provided by the Internet Explorer program. These pages may not display correctly if you have an old version of this program (before version 4.0), or if they conflict with your Internet Explorer 'Security' settings.

Resource Center

- Select **Resource Center** from the **Help** menu.
(Note that Mathcad uses American spellings, hence 'center' not 'centre'.)

This brings up the 'Resource Center' window, shown below.

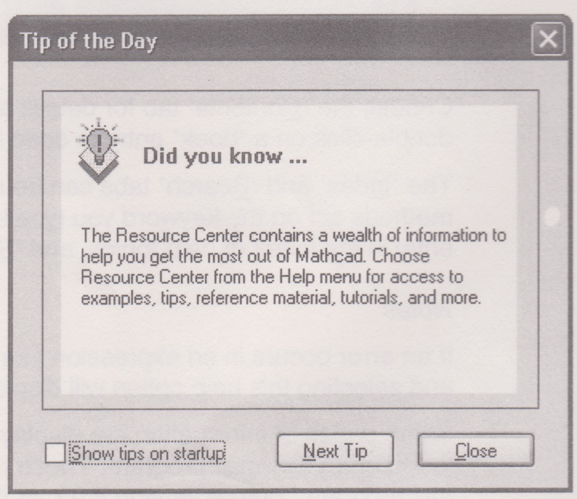


The 'Resource Center' is a Mathcad electronic book (a linked collection of Mathcad worksheets), that appears in its own window, with its own menus and toolbar. Topics are selected by clicking on them, and the two topics that you may find most interesting are 'Overview and Tutorials' and 'QuickSheets and Reference Tables'. You can use the 'Search' button (the binoculars) on the toolbar to search for a particular topic.

Tip of the Day

- Select **Tip of the Day...** from the **Help** menu.

This brings up the 'Tip of the Day' box.



The box contains a tip about Mathcad use. You can see more tips by clicking on the **Next Tip** button, then when you have seen enough, click on the **Close** button.

Notes

The tips are chosen at random from a list.

A tip is shown automatically whenever you run Mathcad if the check box 'Show tips on startup' is ticked.

Electronic version of the full manufacturer's manual

The *Mathcad 2001i User's Guide with Reference Manual* (the full manual, written by MathSoft, the manufacturer) is provided in electronic form, and can be viewed on-screen. It is supplied in PDF ('portable document format') and can be viewed using the Adobe Acrobat Reader program.

! Please note

Your Mathcad work for MST121 and / or MS221 is supported by its own course-specific manual – this Guide ! So it should not be necessary to refer to the manufacturer's on-screen manual, but you may do so if you wish.

Installing the on-screen manual

You will need the MST121/MS221 CD-ROM. (The Mathcad password *is* required too.)

- Follow the instructions in MST121 Chapter A0 to bring up the Mathcad installation screen.
- Click on the bottom button to **Install Online Documentation**.

Details of the installation screens and the responses required from you are given below – you can accept the default settings on all the screens. Note that the Adobe Acrobat Reader program will *not* be installed from the CD-ROM if you already have a suitable version of it on your computer.

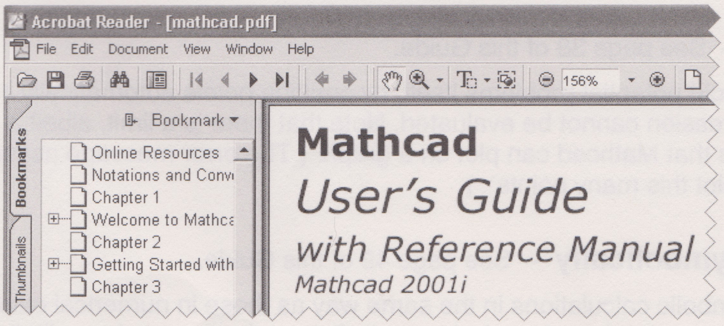
Screen title	Response
Welcome (Online Doc)	**Next>**
Choose Destination Location	**Next>** (The default ...\Doc folder is OK.)
Select Program Folder	**Next>** (The default 'MathSoft Apps' group is OK.)
Start Copying Files	**Next>**
Setup Complete	**Finish** Leave 'Install Acrobat Reader 5.0' ticked, if it appears.
Welcome (Acrobat Reader)	**Next>**
Choose Destination Location	**Next>** (The default ...\Adobe\Acrobat 5.0 folder is OK.)
Information – Thank you !	**OK**

- Close the Mathcad installation window and then, if necessary, click on the **Quit Installation** button on the 'Installing your software' screen. Remove the CD-ROM and store it safely.

Using the on-screen manual

- Open the Start menu ; Programs ; MathSoft Apps ;
  and select the item 'Mathcad Users Guide with Reference Manual'.

  This runs the Acrobat Reader program and displays the first page of the manual.



The 'Bookmarks' at the left-hand side of the screen indicate the contents of the manual, and you can click on these entries to go to a particular chapter.

There are also links within the pages of the manual that you can click on to move around.

! Do NOT be tempted to print out the entire manual – it is over 500 pages long.

Errors and error messages

If Mathcad encounters an error in a worksheet, then it highlights the offending expression in red. Clicking on this expression reveals an error message.

n := 1,2,12

There is an extra comma in this expression.

Such errors fall into two broad categories : **typing errors** and **calculation errors.**

◊ **Typing errors** can be corrected by simply editing the expression. (See page 19 of this Guide.)

◊ However, care is needed when searching for the cause of **calculation errors.**

The problem may not be in the expression marked with the error message, but may instead be due to values set earlier in the worksheet. So you should start by looking for an error in the expression itself, then work back up the page, checking all earlier expressions, which may actually be the cause of the trouble.

After correcting an error, you may need to refresh the screen. (See page 27 of this Guide.)

Undefined variables (and **functions**)

Another common problem and source of calculation difficulties are undefined variables.

These are highlighted in red, and clicking on the offending expression displays an appropriate error message. The cause may simply be a typing mistake, entering the wrong name. Note that variable names are case-specific : **M** and **m** are two different variables in Mathcad.

n := 1,2 .. M

This variable or function is not defined above.

A common slip can be to try to define a new variable using ' = ' (Evaluate Numerically) instead of ' **:=** ' (Definition). Mathcad 'anticipates' this possibility, and will switch to ' **:=** ' automatically.

A less obvious cause may be forgetting to enter a multiplication. In this example, Mathcad treats 'Ah' as a single variable name. (Note the absence of a multiplication dot between the A and the h in the selected expression Ah .)

V := Ah

This variable or function is not defined above.

Note that a variable must be defined (assigned a value) using ' **:=** ' *above* the place in the worksheet where it is first used. See 'Defining variables' on page 12 of this Guide for details. This problem can also affect functions in Mathcad.

No results appear !

By default, Mathcad immediately calculates and updates all the results on the screen.

However, if you are using manual calculation mode, then you must calculate and update the screen yourself by pressing the [F9] function key. (See page 27 of this Guide for further details.)

Graph plotting problems – See page 38 of this Guide.

Mathcad can sometimes avoid potential problems itself, by omitting points automatically in the graph range where the expression cannot be evaluated. Note that there is a limit, albeit a very large one, to the number of points that Mathcad can plot on a graph. (The error message associated with this problem is 'Can't plot this many points'.)

Problems when working symbolically – See page 49 of this Guide.

Mathcad treats errors in symbolic calculations in the same way as those in numerical calculations. It highlights the offending expression in red, and when you click on the expression, will display an appropriate error message.

List of common error messages

The following list of error messages is in *alphabetical* order. It describes the errors most likely to occur in the files for MST121 and MS221, but it does not list all possible error messages.

Information about any error message is available on screen, via Mathcad's help system.

To access this help, click on the offending expression (which will be highlighted in red) and select **Mathcad Help** from the **Help** menu, or press the [`F1`] function key. However, please note that this help is NOT course-specific. (See page 59 of this Guide for further details.)

Error message plus suggested action to correct	**Example**
Can't converge to a solution. Mathcad is unable to compute an answer for a derivative or integral.	$\int_0^1 \sin(100000x)\,dx = \blacksquare$
Can't understand the way this range variable is defined. Check range values. The number after the comma must be between the start and finish of the range.	$n := 1,2..0$
Can't understand this number. Invalid constant (maybe two decimal points). Re-enter or edit the value.	$c := 9.05.$
Found a number with a magnitude greater than 10^307 ... The value is too large to handle. Mathcad can handle only numbers of magnitude up to about 10^{307}.	$2^{10000} = \blacksquare$
Found a singularity while evaluating this expression ... You may be dividing by zero – avoid calculation for this value.	$f(x) := \frac{1}{x} \quad f(0) = \blacksquare$
No solution was found ... The solve block method was unable to find a solution. Try using a different guess. However, there may be no solution.	$\mathrm{Find}(x) = \blacksquare$
The number of rows and/or columns in these arrays do not match. An illegal matrix operation – check the sizes of the matrices.	$\begin{pmatrix} 5 & 7 \\ 1 & 3 \end{pmatrix} + \begin{pmatrix} 6 \\ 9 \end{pmatrix} = \blacksquare$
There is an extra comma in this expression. A comma has been used in an illegal place. A comma may be used to separate only the first two elements of the range.	$n := 1,2,12$
This expression is incomplete. You must fill in the placeholders. A value is missing from an expression, a range or a graph placeholder. Fill in the placeholder.	$n := 1,\blacksquare..12$
This variable or function is not defined above.	(See the previous page for details.)
Value of subscript or superscript is too big (or too small) for this array. A subscript refers to a non-existent array value – check subscript used.	$b_{13} = \blacksquare$
You interrupted calculation ... Mathcad calculation interrupted by you pressing the [`Esc`] key. Calculations can be re-started by pressing the [`F9`] key.	(See page 27 of this Guide.)

Quick reference

Defining variables and functions

		Example	Key sequence
Variable	or type **:** colon ([**Shift**]**;**)	$A := 30$	`A:30`
Subscripted variable	or type **[** left square bracket	$u_0 := 1$	`u[0:1`
Range variable	or type **;** semicolon	$i := 0, 1 .. 10$	`i:0,1;10`
Function	or type **:** colon ([**Shift**]**;**)	$f(x) := 4x^3$	`f(x):4*x^3`

Entering and editing expressions

To **enter** an expression, use the toolbars or the keyboard, and fill in the placeholders.

To **edit** an expression, click on it to obtain the vertical and horizontal blue editing lines. Use the left [←] and right [→] arrow keys to position the vertical editing line, and press the [**Backspace**] key to rub out. (Pressing [**Delete**] will rub out forwards.)

$1 + 9| \times 10 - \frac{30}{5}$

To **select** all or part of an expression, click on it, and then press [**Space**] repeatedly until the editing lines enclose what you require. (Pressing the [**Insert**] key will make the vertical editing line switch sides.)

$1 + 9 \times 10 - \frac{30|}{5}$

Text – To enter text, Insert menu, Text Region or type " double-quote ([Shift]2).

Numbers – Calculations, Displaying results and formatting

To **enter** basic mathematical operators use the 'Calculator' toolbar or the keyboard.

Add **+** subtract **-** multiply ***** ([**Shift**]**8**) divide **/** powers **^** ([**Shift**]**6**).

Use **.** (a full stop) for the decimal point, and round brackets **(** and **)** to group terms.

To **evaluate numerically**, use or type **=** , e.g. type **9*4.8=** to obtain $9 \times 4.8 = 43.2$

To **display** a sequence of values u_0, u_1, u_2, ..., as a **table of values**, display u =, e.g. type **u=** .
(Alternatively, you can define a suitable range variable, say n, and then display u_n =, e.g. type **u[n=** .)

To **format** a result, click in the expression or table to select it, then **Format** menu, **Result...** .

Graphs – Drawing, Formatting

Prior to drawing a graph, define a suitable range variable for the graph range.

To **draw** a graph, use or **Insert** menu, **Graph ► X-Y Plot**, or type **@** ([**Shift**]**'**).

Enter the x-axis expression(s) in the placeholder on the horizontal axis, and the y-axis expression(s) in the placeholder on the vertical axis – to plot more than one curve, separate expressions with commas.

To **format** the traces or axes, click in the graph to select it, then **Format** menu, **Graph ► X-Y Plot...** .

To fix the **scale**, click in the graph to select it, then enter values in the four axis limit placeholders.

Symbolic calculations

Symbolic evaluation ..... → or type [**Ctrl**]**.**

Symbolic keywords, e.g. simplify or type [**Ctrl**][**Shift**]**.simplify**

Other useful symbolic keywords are 'expand', 'factor', 'series' (to obtain a Taylor series) and 'solve'.

Matrices and vectors, Differentiation and integration

Matrix or vector	or type [**Ctrl**]**m**	Derivative	or type **?** ([**Shift**]**/**)
Indefinite integral	or type [**Ctrl**]**i**	Definite integral	or type **&** ([**Shift**]**7**)

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